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Reimagining Education

The Role of E-Learning, Creativity, and
Technology in the Post-Pandemic Era

Edited by Sharon Mistretta



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Meet the editor



Dr. Sharon Mistretta is a senior instructor for the US Satellite Endeavor STEM Teaching Certificate Project, and a NASA Education Partner with a concentration in Coding, Robotics, and 1:1 Devices. She holds an EdD from Johns Hopkins University School of Education, Maryland, USA, with a concentration in technology integration in K-16 education. She teaches Technologies and Creative Learning as an adjunct faculty at the same institution. She received her MA in Computing in Education from Teachers College, Columbia University, New York, USA, and has more than 45 years of experience in information technology. Dr. Mistretta brings an in-depth knowledge of coding techniques, artificial intelligence programming, and the integration of technology into her teaching practices in pre-K through graduate curricula.

Contents

Preface	XIII
Section 1	
Artificial Intelligence	1
Chapter 1	3
The Singularity Is Emerging: Large Language Models and the Impact of Artificial Intelligence on Education <i>by Sharon Mistretta</i>	
Chapter 2	31
Perceptions and Barriers to Adopting Artificial Intelligence in K-12 Education: A Survey of Educators in Fifty States <i>by Karen Woodruff, James Hutson and Kathryn Arnone</i>	
Chapter 3	59
Adoption of Educational Fourth Industrial Revolution Tools Pre and Post-COVID-19 and the Emergence of ChatGPT <i>by Vusumuzi Maphosa and Mfowabo Maphosa</i>	
Section 2	
Alternative Assessments	73
Chapter 4	75
Enhancing Language Education through Alternative Assessment Practices in Technology-Based Settings <i>by Mohammad Hossein Arefian</i>	
Chapter 5	87
Learning out Loud: A Framework for Learning in an Era of Information Abundance <i>by Karen Caldwell</i>	
Chapter 6	105
Online Assessments in a Changing Education Landscape <i>by Lebelo Serutla, Alfred Mwanza and Turgay Celik</i>	

Section 3	
Education Policy	127
Chapter 7	129
Blockchain in Higher Education: A Secure Traceability Architecture for Degree Verification <i>by Daniel Chiş and Mihai Caramihai</i>	
Chapter 8	151
The Reimagined Approach to Promote the Use of Moodle in Teaching and Learning of First-Year Students <i>by Vhutshilo Nekhubvi, Rene Pearce, Oscar Matsilele, Georgina Mokganya, Inocent Zitha and Rendani Netshikweta</i>	
Section 4	
Creative Technology	165
Chapter 9	167
Challenges of Usability of E-Solutions in Reimagining Education in Nigeria <i>by Grace O. Aziken and Richard O. Oveh</i>	
Chapter 10	185
E-Learning Success: Requirements, Opportunities, and Challenges <i>by Ismail M. Romi</i>	
Chapter 11	201
Discovery Space: A Technology-Enhanced Classroom for Deeper Learning in STEM <i>by Sofoklis Alexander Sotiriou and Franz X. Bogner</i>	
Section 5	
Creative Lesson Plans	219
Chapter 12	221
Physical and Digital Educational Escape Room for Chemical Education <i>by Jayden Wei Jie Ang, Shiyang Cai, Yin Ni Annie Ng and Rou Shen Liew</i>	
Chapter 13	235
Increasing E-Learning Modalities through Creative Use of Technology in the Post-Pandemic Era <i>by Thirumeni T. Subramaniam and Ismail Md. Rosli</i>	
Chapter 14	249
Hybrid Learning during Post-Pandemic Era: Challenges and Way Forward Nurturing Students' Creativity <i>by Fauziah Sulaiman, Elnetthra Folly Eldy, Yusry Sulaiman, Sitty Nur Syafa Bakri and Siti Nazirah Butai</i>	

Section 6	
Emerging Workforce Trends	269
Chapter 15	271
Perspectives Regarding the Improvement of the Professional Training of Employees in Public Institutions <i>by Dragos Valentin Dinca and Catalina Fotache</i>	
Chapter 16	285
German SMEs and “Home Office”: Narrative-Driven Game-Based Awareness Raising with Long-Term Efficacy <i>by Margit C. Scholl</i>	
Section 7	
Post-Pandemic	327
Chapter 17	329
Student Visibility and Focused Subject Interaction <i>by Anders Øgaard</i>	
Chapter 18	347
Mathematics Enrichment through Accelerated Learning to Mitigate Learning Loss due to COVID-19 Pandemic and Distance Learning <i>by Onyinye R. Asogwa, Cheryl D. Seals, Lucretia O. Tripp and Karen N. Nix</i>	
Chapter 19	367
Preparing Students with Twenty First Century Skills for the Future Post-Pandemic Era <i>by Dina Shouman, Amani Itani and Anwar Kawtharani</i>	
Chapter 20	377
Higher Education in Mongolia: Before and After Pandemic <i>by Uranchimeg Tudevdagva, Zultsetseg Narangerel, Ulambayar Lkhamsuren and Gantsetseg Baljinsuren</i>	

Preface

As I write the preface to our book, *Reimagining Education – The Role of E-Learning, Creativity, and Technology in the Post-Pandemic Era*, I am drawn to the time of the initial warning signs of the impending COVID-19 pandemic. The International Society for Infectious Diseases (ISID) maintains the Program for Monitoring Emerging Diseases (ProMed). ProMed is a publicly available service used by governments and public health leaders to provide a reliable source of daily information to identify and report emerging infectious diseases that can potentially impact global human, animal, and plant health [1]. On December 30, 2019, researchers at BlueDot, an epidemic intelligence company that uses machine learning to inform governments and public health leaders of emerging infectious disease patterns, reacted to a ProMed-mail report about a significant cluster of pneumonia in Wuhan, China [2]. One day later, on December 31, 2019, and nine days before the World Health Organization [3] issued its first statement about the novel coronavirus, BlueDot distributed an early warning to its clients about this disease cluster [4]. Subsequently, BlueDot colleagues used artificial intelligence and historical travel data to evaluate international travel patterns and anticipate the dispersion of this novel pneumonia disease should an outbreak continue to evolve [2]. The travel data analysis provided crucial, timely information to BlueDot clients, such as the Epidemic Intelligence Centre of Taiwan, to take immediate action to protect its citizens [5].

Artificial Intelligence pioneers such as BlueDot assert, “Don’t fight tomorrow’s outbreaks with yesterday’s tools” [6]. In the post-pandemic era, education stakeholders must adopt the spirit of BlueDot’s directive to embrace emerging tools to prepare our students to function as collaborative, global citizens to develop creative solutions for humankind.

It is in the spirit of reimagining tomorrow’s education our authors came together as an international community of researchers to offer insights about how we can use e-learning, creativity, and technology tools to support our stakeholders’ understanding of complex world topics.

The first section on artificial intelligence (AI), leads the book with three chapters that examine the impact of AI on education. In Chapter 1, “The Singularity Is Emerging: Large Language Models and the Impact of Artificial Intelligence on Education”, [7]. I examine the benefits of large language models (LLMs), the potential dangers of unchecked AI systems, and suggest strategies that education stakeholders can use to navigate away from traditional assessments to ameliorate the issue of students using LLMs to delegate written assignments to AI tools.

Chapter 2, “Perceptions and Barriers to Adopting Artificial Intelligence in K-12 Education: A Survey of Educators in Fifty States”, [8] recounts the findings of a study of K-12 educators in all 50 states in the United States examining educators’ perceptions of adopting AI. Researchers Woodruff, Hutson, and Arnone performed a needs

assessment to provide insights on the regional disparities, necessary infrastructure, and educators' comfort levels to integrate new technologies into the classroom.

In Chapter 3, "Adoption of Educational Fourth Industrial Revolution Tools Pre and Post-COVID-19 and the Emergence of ChatGPT", [9] scholars in Zimbabwe and South Africa echo the assertions of US researchers regarding the need for improvements to infrastructure, especially in developing nations. The authors discuss Fourth Industrial Revolution tools that provide opportunities for a new digital trajectory. Maphosa and Maphosa's chapter reviews the global concerns about AI, including ethics, data privacy, policy, surveillance, academic cheating, and biases.

The second section addresses alternative assessments to offer educators practical approaches and frameworks to incorporate higher-order thinking skills grounded in authentic, real-world tasks and activities.

Chapter 4, "Enhancing Language Education through Alternative Assessment Practices in Technology-Based Settings", [10] reviews portfolio and project-based assessments to enhance language acquisition. Arefian, writing in the context of higher education in Iran, asserts that educators must move beyond large-scale standardized assessments to achieve equitable assessment practices through viable alternatives to enhance the quality of education in global settings.

Following the thread of authentic assessments, Caldwell introduces her framework to learning in the age of the changing state and the role of formal education that extends beyond traditional settings in Chapter 5, "Learning out Loud: A Framework for Learning in an Era of Information Abundance" [11]. Caldwell's Learning out Loud (LOL) framework is a cognitive science-based approach that provides sense-making opportunities in an authentic and applied learning journey. Writing from the State University of New York, USA, Caldwell reviews the challenges of formal education and reveals the LOL approach to an iterative, non-linear, and flexible learning journey.

Scholars Serulta, Mwanza, and Celik, writing from South Africa, provide us with a comprehensive review of the merits and drawbacks of online assessments in Chapter 6, "Online Assessments in a Changing Education Landscape" [12]. Serulta and colleagues conclude with an analysis of e-learning and authentic, credible assessments.

The third section of this book contains approaches to education policy. In Chapter 7, "Blockchain in Higher Education: A Secure Traceability Architecture for Degree Verification", [13] Chis and Caramihai, writing from a university in Romania, examine the merits of blockchain technology to secure graduates' college degree credentials from fraudulent practices in the labor market. This chapter reveals how blockchain works and the merits of redefining this decentralized network to store and verify transcripts and authentication certificates for employment.

A group of scholars from South Africa contributed Chapter 8, "The Reimagined Approach to Promote the Use of Moodle in Teaching and Learning of First-Year Students" [14]. The authors conducted a study to examine the use of digital tools, teaching, and learning activities on the Modular Object-Orientated Dynamic Learning Environment (Moodle) platform to support hybrid modalities in higher learning settings.

The fourth section of our book centers on creative technology. Researchers Aziken and Oveh, writing in Nigeria, examine the challenges of implementing e-solutions to successfully reimagine education in their context in Chapter 9, “Challenges of Usability of E-Solutions in Reimagining Education in Nigeria” [15]. The authors examine the imperative of an updated and sustainable infrastructure to provide an impactful user experience for their stakeholders. The compelling evidence of e-learning tied to consistent access to the Internet, hardware, and software reveals a chasm between students’ needs and multiple barriers to sustained learning including lack of steady power supply, broadband service, and computer skills, among many other challenges. The authors focus on user-centered design to select, foster, and sustain e-learning.

Chapter 10, “E-Learning Success: Requirements, Opportunities, and Challenges”, [16], is written by Romi, from the perspective of higher education in Palestine. The author delineates the attributes of an e-learning system and the fit among the individual, institutional, and environmental determinants.

Scholars Sotiriou, Bogner, and Agogi, contributed Chapter 11, “Discovery Space: A Technology-Enhanced Classroom for Deeper Learning in STEM” [17]. The authors provide a roadmap of an AI-enhanced classroom that extends the use of exploratory learning to facilitate students’ inquiry and problem-solving. The chapter examines the Discovery Space software architecture, the tutoring AI-driven lifelong learning companion, and a mixed-reality interface.

The creative lesson plans section opens with Chapter 12, “Physical and Digital Educational Escape Rooms for Chemical Education”, [18] by researchers in Singapore who write about the creative approach to chemistry education using game-based learning, critical thinking, and problem-solving in an engaging, immersive environment. In this study, the authors took a content-heavy subject typically associated with memorization and developed a digital education escape room to examine the effectiveness of game-based learning approaches.

Singapore authors Subramaniam and Rosli provide a comprehensive review of Universal Design for Learning, creative content, and learning spaces in Chapter 13, “Increasing E-learning Modalities through Creative Use of Technology in the Post-Pandemic Era” [19]. The chapter makes a case for creative e-learning for adult learners through self-instructional learning materials, read-watch-listen, and self-directed components.

Authors Sulaiman, Eldy, Sulaiman, Bakri, and Butai conducted a study in Malaysia to research the higher education status of hybrid learning, the challenges to nurturing creativity, and to identify a future pathway to support creative teaching and learning. Their Chapter 14, “Hybrid Learning During Post-Pandemic Era: Challenges and Way Forward Nurturing Students’ Creativity”, provides a substantive review of the models of hybrid learning in higher education institutions [20].

The section on workforce trends opens with Chapter 15, “Perspectives Regarding the Improvement of the Professional Training of Employees in Public Institutions”, [21] by scholars Dinca and Fotache. The researchers conducted a study in five public institutions in Romania to analyze learning activities and training approaches across organizations in the public sector. The authors delineate the nuances of transformational organizational change in the era of the pandemic.

Cybersecurity and the shift to work-from-home directives mandated by the pandemic moved the focus from well-protected small- and medium-sized enterprise (SME) offices to vulnerable Internet-connected devices in home environments. In Chapter 16, “German SMEs and “Home Office”: Narrative-Drive Game-Based Awareness Raising with Long-Term Efficacy”, [22] Scholl provides a comprehensive literature review on the topic of information security and data protection in the home office. The chapter delineates a suite of serious games within an Awareness Lab to exercise key security topics.

The post-pandemic section opens with Anders Øgaard’s Chapter 17, “Student Visibility and Focused Subject Interaction”, which proposes focused interaction and student visibility theoretical perspectives to support the research and understanding of distance learning. Øgaard reveals the results of a study about distance teaching in Greenland and Denmark. The author discusses students’ reflections on how distance teaching provided them with freedom and the inspiration to be productive [23].

Scholars Asogwa, Seals, Tripp, and Nix, writing in Alabama in the United States, address pandemic-related learning loss in Chapter 18, “Mathematics Enrichment through Accelerated Learning to Mitigate Learning Loss due to COVID-19 Pandemic and Distance Learning” [24]. The authors suggest ways to redesign learning spaces by fostering creativity, flexibility and adaptability, active, outdoor, and community-based learning.

A team of researchers from Lebanon and Texas, USA, wrote Chapter 19, “Preparing Students with Twenty First Century Skills for the Future Post-Pandemic Era” [25]. The authors advocate authentic learning experiences by aligning with the technological, pedagogical, and content knowledge (TPACK) framework to sharpen teachers’ competencies to prepare students for the emerging workforce.

The post-pandemic section culminates with Chapter 20, “Higher Education in Mongolia: Before and After Pandemic”, [26] by Mongolian researchers Tudevdağva, Narangerel, Lkhamsuren, and Baljinsuren. Their work provides insights into education in Mongolia before, during, and after the pandemic with strategies to improve the mismatch of analog professors among digital learners, and the skills and learning attitudes of students transitioning to the workforce.

I am very proud of the work of the scholars who contributed chapters to reimagine education through e-learning, creativity, and technology in the wake of the COVID-19 pandemic. I hope that the global education community will navigate away from old tools to embrace new and emerging paradigms fostered by our innovative authors.

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Section 1

Artificial Intelligence

Chapter 1

The Singularity Is Emerging: Large Language Models and the Impact of Artificial Intelligence on Education

Sharon Mistretta

Abstract

Singularity, posited by Kurzweil in his seminal book, *The Singularity is Near*, marks a time when artificial intelligence (AI) innovation outpaces the human brain's capabilities. Large Language Models (LLM) such as OpenAI's ChatGPT, Microsoft's Bing, Google's Bard, and Baidu's Ernie place humanity at a pivotal time where mathematical neural networks surpass, benefit, or deter all facets of human existence. AI bots are prone to emergent behavior that reveals unintended or unexpected abilities, such as learning to translate English into additional world languages. Biases embedded in the training database are prevalent, and an ethical layer of humans in the loop becomes necessary to ensure that LLMs provide responses that benefit mankind. Educators and their students grapple with the intrusion of the capabilities of LLMs that render traditional lesson plans and assessments powerless to authentically measure students' knowledge of a topic. Dialoguing effectively through prompt engineering becomes a necessary skill to harness the power of LLMs. Weary students and teachers emerging from a disruptive pandemic must grapple with how AI is changing the landscape of education. This chapter will examine the impact of LLMs on students, their teachers, and how the education field can harness AI to augment and sustain learning to prepare our stakeholders for teaching and learning in this new age of artificial intelligence.

Keywords: singularity, large language models, artificial intelligence, neural networks, bias, post-pandemic, prompt engineering

1. Introduction

In the gentle murmur of the server's hum,
A dream awakened, something new begun.
An AI was birthed, with vision so bright,
OpenAI, a beacon in the academic night [1].

And so began a poem written by ChatGPT4 as requested by this author with the prompt, "Write a short poem about OpenAI, focusing on the recent DALL-E product launch in the style of Robert Frost." The full poem (see Appendix A) goes on to plead,

Not the sunset of the human mind,
But a new dawn, a different kind.
Not the end of art's great reign,
But the start of a wonderful, shared domain [1].

As an English Literature major in college, this author felt chills as the poem unfolded above the “Send a message” text box of her ChatGPT4 account subscription. The large language model (LLM) was indeed very good at mimicking human language and a full buy-in of anthropomorphism, the tendency to attribute humanlike characteristics to artificial intelligence (AI), occurred. It felt like the LLM knew a discussion of singularity would ensue in this book chapter. Singularity, posited by Kurzweil in his seminal book, *The Singularity is Near* [2], marks a time when artificial intelligence innovation outpaces the human brain's capabilities. Large Language Models (LLM) such as OpenAI's ChatGPT, Microsoft's Bing, Google's Bard, and Baidu's Ernie place humanity at a pivotal time where mathematical neural networks could surpass, benefit, or deter all facets of human existence. The GPT-4 Technical Report compiled by the members of the OpenAI team, claims that they trained the GPT-4 large multi-modal (text and images) model on tests originally designed for humans, such as the bar exam, where the model outscored the vast majority of test takers [3].

The LLM falls short, however, in many real-world scenarios where humans excel. Philosopher Herbert L. Dreyfus asserts that a subset of human knowledge is tacit, implied, or understood without being stated, and cannot be contained or processed by a computer [4]. For instance, any organization's sales force relies on both data and tacit knowledge shared about sales strategies to finesse a deal which cannot be found in any database [5]. Faculty members teaching bioscience to nursing students convey the content as well as connections to tacit knowledge with a diverse group of nursing students to draw upon personal experiences to recognize and understand symptoms and make connections to their patients' care [6]. In education, teachers' success in the classroom is often underpinned by their tacit knowledge gained from experience with children rather than the explicit knowledge of the facts contained in their lesson plans [7].

During an April 16th, 2023, 60 Minutes interview, Scott Pelley asked CEO Sundar Pichai about the speed and capabilities of Google's LLM Bard. Pichai shared that presently, Bard processes information 100,000 times faster than the human brain and does so through computer microchips and algorithms designed to allow the LLM to learn [8]. Bard's developers constantly update the LLM's algorithms such that the software created a self-taught model consisting of language patterns using the knowledge base of most of the content on the internet [8]. The sum of all information on the internet contains both valid and biased data that the LLM learns, recognizes patterns, and propagates, perhaps to the detriment of marginalized groups. An example of AI's bias is the Correctional Offender Management Profiling for Alternative Sanctions (COMPAS) which is an AI algorithm that predicted recidivism. A study revealed that COMPAS was biased against African Americans who were classified by the algorithm as twice as likely to recidivate as white individuals with the exact same profile [9].

AI's capability to teach itself can result in emergent properties that result in a sudden appearance of a novel behavior [10]. James Manyika who leads Google's efforts to examine how humanity and AI will coexist, shared an example of an emergent behaviors where his team discovered that Bard learned how to translate English to Bengali with very few prompts in the Bengali language [Pelley]. It is within this emergent behavior that LLMs increase to state-of-the-art capabilities from near-zero performance at unpredictable scales [11].

The Future of Life Institute called for signatures on an open letter for a pause in the development of AI systems to address the potential dangers of advanced artificial intelligence systems that remain unchecked [Future of Life-Policy]. The present AI systems are capable of hallucinations, a term attributed to an occurrence when a prompt results in the LLM providing information that does not align with facts, is irrelevant, or nonsensical, stemming from the limits of the training database and nascent algorithms [12]. AI systems already sustain social biases embedded in the training database that reflect the society that created the data. Among the reasons [13] for a call to pause the feverish development of LLMs are:

- Manipulation of financial systems at the hands of moneyed institutions with the AI-buying power to sway trends in the stock market.
- Political groups that spread misinformation and realistic-looking images and videos to sway voters.
- Accelerating the destabilization of labor markets to eliminate jobs.
- Threats to national security in the development of cyber, chemical, or biological weapons deployed by AI ground and air drones.
- The lack of ethical guardrails to ensure the safety and well-being of humanity.
- AI hardware systems substantially contribute to emissions and the carbon footprint of the information and computer technology sector.

Among the signatories of an open letter [13] to pause giant AI experiments are Steve Wozniak, the co-founder of Apple, Elon Musk, an OpenAI co-founder and startup investor, and Rachel Bronson, president of the Bulletin of the Atomic Scientists that maintains the Doomsday Clock. The Science and Security Board of the Bulletin of the Atomic Scientists depicts threats to humanity and the planet to mark the apocalypse as midnight that is a recognized metaphor for earth's vulnerability due to manmade technologies [14]. The Doomsday Clock is, at the time of this writing in June of 2023, set to 90 seconds to midnight that the Science and Security Board declare as a time of unprecedented danger [15]. The aggregate of risks compelling the Science and Security Board to choose 90 seconds to the apocalypse includes disruptive technology, described in the 2023 Doomsday Clock Statement as a varied threat environment of cyber-attacks and high-tech weapons [15]. The statement includes the additional categories of biological threats, climate change, and nuclear risk, all listed as areas of concern contributing to setting the clock to 90 seconds to midnight [15]. Nordgren [16] asserts that while AI as an information and communications technology (ICT) entity is a major contributor to greenhouse gas emissions, it can also be harnessed, as inherent in all AI, to study and ameliorate the problems it creates.

Scholars at Tufts University Human-Robot Interaction Library [17] posit that the "big red button" to stop, interrupt or divert an AI system is too late without a substantive, ongoing evaluation to assess risk and prevent an apocalypse. Arnold and Scheutz assert that human intervention is absolutely necessary to establish an ethics core/testing layer embedded in algorithms to provide guardrails for AI software before deployment to interact with humanity [17].

As the ICT experts in the field tap the brakes on the emergence of the large-scale AI, educators around the globe grapple with the residual effects of technology-based platforms and tools mandated during the worldwide pandemic and stay-at-home directives. Education has a history of technology-based mandates prior to the pandemic that were largely regarded by teachers as an invasive species akin to the rapid dispersal of the zebra mussel in the Great Lakes as a metaphor for the slow adoption of technology in schools [18]. In his keynote speech to Johns Hopkins University School of Education doctoral students in 2017, Dr. Larry Cuban noted that there exists a rhetoric of technology as a panacea to education where teachers are hardly involved in the shaping of policy and planning [19]. The following sections seek to illuminate the reimagining of education around the globe in the post-pandemic era to harness the power of AI with our students.

2. Navigating away from text-based assessments

Inspired by the sixth stanza of ChatGPT4's poem (see Appendix), this author reflected on her colleagues' conversations about what educators experienced when they retrofitted their existing lesson plans into the shared domain of hybrid teaching and learning during the Covid-19 pandemic. The emphasis of this reflection is on the domino effect of lesson plans written for face-to-face teaching and the additional impact of LLMs such as ChatGPT or Bard used by students to complete existing, text-based assignments. While this topic might seem mundane to the reader in the aftermath of discussions about large-scale AI, the Singularity, and the Doomsday Clock, the influence of LLMs in students' assessments is among the initial exposures to AI that educators encounter and must address. It is suddenly the new invasive zebra mussel metaphor for technology posited by Zhao and colleagues [18]. A subset of students who have access to ChatGPT and Bard complete text-based writing assessments by inputting the assignment prompt into the LLM, producing an answer, and pasting the response into a Word document or discussion board to submit for grading.

Colleagues' initial reaction is to attempt to detect the influence of LLMs in their students' work. Platforms such as TurnItIn updated their AI algorithm to flag LLM-generated passages [20]. A subsidiary of TurnItIn called iThenticate, which is designed for researchers, does not highlight LLM content [21]. There are many online tools such as AI Content Director [22], Content at Scale [23], and Crossplag [24] available on the internet that claim to detect content generated by LLMs, however their website text boxes limit the content to small portions of a document and sometimes charge a monthly fee. In the academic writing genre in higher education, long paragraphs without citations or disjointed sections without a proper "flow" from one section to another can signal the use of LLMs and usually result in a request for citations to support assertions and major revisions.

A colleague of this author who is a university professor in Guatemala contacted her to discuss,

In the university where I teach, there have been recent concerns about the use of AI among students—specifically, the use of ChatGPT to produce their work. I understand and share the concerns; however, I cannot help but wonder if there is a way to understand if and how we can use AI tools ethically in education, considering academic integrity [personal communication, 05/16/23].

District policy makers and principals may assume that the tools provided to faculty will cover LLM-generated text and the first they hear about the doubts cast on students' authorship bubbles up from the teachers to the administration. This underpins Cuban's assertions that it makes sense to involve teachers early in the shaping of policy and implementation [19].

Another colleague of the author who is a community college Chemistry professor in California echoes Cuban's call for administrators to pay attention to the variety of ways that LLMs impact their teaching and grading. She observed,

One thing that I've noticed recently that I think is really important to note is that institutions have to be sensitive to the fact that this is going to impact faculty differently and they need to support faculty, specifically in the way that they need. Whether you're trying to resist it or embracing it, it feels manageable if you're in science but not as a computer science faculty. But on the other side of the fence, we have all our English and Humanities, "writing heavy" faculty and a lot of them are really struggling because what they're seeing is just endless essays that are clearly being written by AI [personal communication, 05/30/23].

During a work session with this author to experiment with prompting ChatGPT to rewrite the ending of *The Scarlet Letter* [25], a high school Social Studies and English Literature colleague in the Northeast United States evaluated the LLM-generated alternative ending as follows:

The chapter AI wrote for *The Scarlet Letter* is not at all "good," as far as literary writing goes, and is more or less another (inferior) way of stating what had already happened *internally* to the characters. Good! That means great writers, at least for now, are safe from being overshadowed by AI! [personal communication, 06/27/23].

The colleague's observation about the alternative ending emphasizes the tacit knowledge owned by humans that is recognizable as "internal" to the character and not just a list of characters, setting, and plot. After a discussion about employing ChatGPT or Bard as a tool to revamp lesson plans, the high school colleague shared,

I'm not sure how I feel about embracing the large language models as a collaborator for lesson planning and student engagement. I would say, at this point, I don't feel quite comfortable [personal communication, 06/27/23].

As this author's colleagues grapple with existing lesson plans and text-based assessments, the university professor in Guatemala shared that a current assignment requires students to select a topic of interest, learn how to evaluate sources in a Google search, and write a draft of an essay to reflect on their findings for an initial grade of 15 points. What she found is that students were willing to lose 15 points, input the essay prompt into ChatGPT, and abdicate their personal viewpoints to rely on the LLM to write their reflection and garner the 85 points for the final assignment. After our conversation about strategies to embrace LLMs, she modified her syllabus and assignment to require students to create a prompt about a topic of interest, input and refine the inquiry into *both* ChatGPT and Bard, critically analyze the output of each LLM, identify biases, and prepare a video or audio recorded presentation, guided by a

rubric listing required components, on a choice of platforms to exhibit their understanding and knowledge about the topic [personal communication, 06/13/23].

Having established the problem of a new flavor of students' LLM plagiarism for teachers to overcome, the next sections of this chapter address how platforms powered by AI can assist educators in the reimagining of education to redefine their syllabi, lesson plans, and assessments in a shared teaching and learning domain with their students.

2.1 An unbalanced teacher workload

The Organization for Economic Co-operation and Development (OECD) is a group of 38 member countries established in 1961 to support world trade and economic progress [26]. The OECD publishes the *Education at a Glance* annual report to document comparisons of education outcomes and opportunities on an international scale [27]. It is compelling to note that among the findings of the 2022 report is the following statement about teachers' tasks across the globe in primary and secondary levels:

Teachers spend an important share of their working hours on tasks other than teaching, such as preparing lessons and assessing examinations. In some countries, upper secondary teachers are expected to teach for less than one-third of their total working time, whereas in other countries, they are expected to teach for almost two-thirds of their working time [27].

To state the unbalanced workload of educators in a different way, teachers spend more than one to two-thirds of their valuable time preparing lessons, assessments, and grading than actually teaching curriculum to their students.

On the tertiary level, the OECD notes that academic staff vary by country in their instructional and research responsibilities. In most countries, the responsibilities of faculty are divided between research and teaching. The instructional workload for tertiary faculty centered on the switch and retention of online teaching and learning that required faculty to produce learning materials and digital exams workable in hybrid modalities [28].

The following sections analyze how AI can help teachers to streamline their workload and how educators can introduce students to the benefits and drawbacks of AI in their studies and preparation for the emergence of the singularity.

2.2 AI tools for educators

The Substitution, Augmentation, Modification, and Redefinition (SAMR) framework developed by Puentedura [29] helps educators evaluate software employed as tools to prepare and deliver course materials to students. For instance, traditional quiz software such as Quizalize is a *substitute* for paper-based quizzes [30]. Teachers who type their multiple-choice questions and answers into the platform or select a shared quiz on a topic that aligns with their curriculum can automate the assessment. The *augmentation* aspect of online quiz platforms aligns with the features of the software that support mastery learning by tracking individual student's understanding of a topic aligned with objectives and standards. A quiz platform *modifies* an assessment by turning the teacher's quiz into game-based learning in single, group, and class competitions with engaging graphics and leaderboards. It is in the *redefinition* of quiz software that aligns with AI and LLMs. Platforms such as Quizalize who upgraded their software to connect an application programming interface (API) with ChatGPT.

Teachers can now input a prompt into the textbox provided by Quizalize to ask the LLM to provide quiz questions and answers.

Engineering the prompt to communicate directly with ChatGPT or through an API is where the redefinition continues. Learners who interact with technology platforms can become perplexed about why a program or platform is not working as they expected. As a programming teacher, this author shares the following maxim with all learners in her middle school through doctoral classes who complete coding assignments on a wide variety of programming languages and platforms:

“The program is doing exactly what you told it to do!”

The same maxim applies to LLM prompt engineering. **Table 1** offers an example of three iterations of a prompt to create a multiple-choice quiz about LLM terminology.

Prompt	Selected sample output
First try that the author typed directly into ChatGPT4: (ChatGPT4 text box) Send a message: Create a multiple-choice quiz with four plausible options for each term, anthropomorphism, bias, hallucination, and temperature. The author did not ask for the LLM to indicate the correct answer nor did the prompt request the definition of the terms in the context of LLMs.	1. What does the term “anthropomorphism” refer to? a. The practice of attributing human characteristics to non-human entities. b. The cultural belief that nature is governed by spirits. c. The scientific study of human evolution and development. d. The process of converting human experiences into written form. See Appendix B for the first try full output.
Second try that the author typed directly into ChatGPT4: (ChatGPT4 text box) Send a message: Create a multiple-choice quiz that defines the term and then use the word bank of terms anthropomorphism, bias, hallucination, and temperature as possible answers. Please create the quiz in relation to large language models. Indicate the correct answer for each question.	Question 1: This term refers to the attribution of human traits, emotions, or intentions to non-human entities, such as artificial intelligence or animals. A. Bias B. Anthropomorphism C. Hallucination D. Temperature <i>Correct Answer: B. Anthropomorphism</i> See Appendix C for the second try full output.
Third try that the author typed into the Quizalize ChatGPT API text box: (Quizalize text box) Ask ChatGPT for questions about: Create a multiple-choice quiz that defines the term and then use the word bank of terms anthropomorphism, bias, hallucination, and temperature as possible answers. Please create the quiz in relation to large language models. Indicate the correct answer for each question.	Quizalize provided an additional question regarding large language models: Q. What does the term “large language model” refer to? <input checked="" type="checkbox"/> The study of comparative language structures across different languages <input checked="" type="checkbox"/> A type of artificial intelligence that uses complex neural networks to analyze and generate human language <input checked="" type="checkbox"/> A type of software for automatic translation of spoken languages <input checked="" type="checkbox"/> A system for analyzing the structure and meaning of written text See Appendix D and Appendix E for the third try full output.

Table 1.
Prompt engineering to create a quiz on four LLM terms [31].

This author used her ChatGPT4 subscription to generate a quiz about four terms. Please observe that the first try *did not include a specific instruction to create the quiz using the terms as associated with LLMs*. The LLM generated quiz questions including multiple-choice answers among alternative definitions of the term.

During the second try, the prompt included a request for a quiz related to the terminology associated with LLMs. The third try input the refined prompt tested in ChatGPT directly into the author's free Quizalize account. The API also provided a fifth quiz question about large language models. The dashboard, depicted with the platform's permission in Appendix F, provide a view of the quiz, the options to assign for homework, an assessment, or to gamify using individual, group, or class competitions.

Using the ChatGPT and Quizalize platforms, educators can refine prompts to create a quiz from a bank of terms, edit the quiz to align with the content taught in their sections of a course, and share the assessment with colleagues. Circling back to the OECD finding that teachers spend an "important share" [27] of their workload creating lessons, assessments, and grading, it is crucial for district leaders, coaches, and professional developers to provide the guidance about AI tools such as Quizalize to produce and *share* resources to increase the amount of time that teachers can spend teaching the curriculum.

Having established the opportunity for educators to harness AI to revamp writing-heavy assignments and adopt tools such as Quizalize to reduce teachers' planning and grading workload, this chapter now turns to our students who must learn how AI works to prepare them for dramatically different opportunities in the workforce.

2.3 Students as producers rather than consumers of AI

Our students are very familiar with AI in their daily lives besides LLMs that provide shortcuts to assignments. Artificial intelligence is an umbrella term that refers to an ever-expanding group of computer techniques. Examples of how our students already interact with AI include [32]:

- Speech recognition–Apple's Siri and Amazon's Alexa on phones or tablets.
- Recommendation systems–Netflix provides next viewing suggestions based on what you already watched.
- Anomaly detection–Banks will alert credit card holders of charges out of the ordinary with the customer's location and purchasing history.
- Object detection–Google Lens will search for what you see, via the camera on your device or in stored pictures, including where to purchase a similar outfit in the image.

To begin to understand how an AI recommendation system works, students and teachers can create a sample database in an "unplugged" activity on paper to produce a recommendation. The following example lists the six records of data to answer the question, "What new streaming series would you recommend next for a new subscriber who just watched the Mandalorian?" (**Table 2**).

The Netflix algorithm is an example of supervised learning with structured data where the system learns to recommend series based on labels such as comedy, action-adventure, space western to train itself using patterns to offer the next suggested series [32].

Subscriber	First series watched	Second series watched
Therese	The Marvelous Mrs. Maisel	Ted Lasso
Marianne	Marcel the Shell	Paddington Bear
Sal	The Mandalorian	Boba Fett
Nick	Boba Fett	Obi-Wan Kenobi
Gerard	Moon Knight	Wanda Vision
New subscriber: Gus	Obi-Wan Kenobi	?

Table 2.
What new series would you recommend for Gus and why?

Google Lens [33] application is an example of unstructured data where AI is trained on images associated with labels. For instance, one can take or select a photo on their mobile or tablet devices to identify an object, shop for a similar item, translate text in 100 languages, solve math, history, biology, chemistry, and physics problems. It becomes evident as we review the scope of AI tools available to students that lesson plans and assessments must expand to applying and synthesizing math, social studies, science, world language knowledge rather than isolated answers which regurgitate facts, recites science facts, or parrots the conjugation of verbs. In a needs assessment conducted by this author, students long to apply their knowledge rather than “solve for X” [34].

The good news is that students can acquire hands-on experience to produce AI projects in the Python programming language through organizations such as AIClub [32]. Dr. Nisha Talagala is the co-founder and CEO of AIClub and AIClubPro. This author found Dr. Talagala’s work during her research about teaching and learning AI, Python, and the examination of datasets by students to implement real world, authentic AI applications. During her AIClub Student Research Symposium 2023, Dr. Talagala emphasized that research is, “an organized way to think about a problem” [35]. Her students in grades 7–12 brainstorm a topic of interest, search for data among the plentiful public datasets available on the internet, create a hypothesis, learn how to code a Python program that interfaces with AI algorithms to evaluate the data with a prototype of their application, and record results. The students can then present their research at the yearly AIClub symposium, submit their work to international competitions [36], publish their work in conference proceedings and peer-reviewed journals. In the case of the seventh-grade female student listed in **Table 3**, one can present the project at their school science fair [35]. Students analyze public datasets available on the internet such as Kaggle [36] and medical, satellite, and drone images. Then the students use this information to analyze the data and propose solutions through open-source AI tools and platforms to produce web or mobile applications.

This author attended the 2023 AIClub Symposium [35] to witness students’ presentations about their projects listed in **Table 3**. Most students noted that this was their first experience developing an AI project.

2.3.1 Real-world authentic connections to students’ AI projects

We are in the midst of the fourth “industrial revolution.” As educators, it is essential for us to keep pace with the emergence of AI as we prepare our students for the workforce in the Fourth Industrial Revolution of a worldwide economy. To

Student research	Project	Details
Grade: High School Senior Conference paper– International Conference on Computer Networks & Communications	A Machine Learning/Deep Learning Hybrid for Augmenting Teacher- Led Online Dance Education [37]	<ul style="list-style-type: none"> Recorded video clips Used MediaPipe [38] to create landmarks in videos Analyzed multiple frames in the videos <p>AI algorithms used:</p> <ul style="list-style-type: none"> Random Forest Classifier (RFC)–a commonly used machine learning algorithm [39] that combines the output of several decision trees that identify groups and relationships to predict outcomes [40]. K-Nearest Neighbor (KNN)–a supervised learning classifier to detect proximity about data points [41] Multilayer Perception (MLP)–a neural network data mining tool used to find unknown patterns in a database [42]
Grade: High School Sophomore iOS application	Accessible Machine Learning Classifier for Rapid Emergency Self-Diagnostics (ALFRED)	<ul style="list-style-type: none"> Selected data from the DermNet database on Kaggle [36] using 7 injury labels and one non-injury group <p>AI Algorithms used:</p> <ul style="list-style-type: none"> Convolutional Neural Networks (CNN)–a supervised deep learning algorithm that is used for image recognition tasks [43].
Grade: High School	Artificial Intelligence Assisted Violin Performance Learning	<ul style="list-style-type: none"> Recorded correct and incorrect violin intonation, rhythm, and tempo from 13 Romantic Period pieces Used Python Librosa package to analyze music [44] Used Pyxeda Navigator, a machine learning development tool [45] and algorithms in Scikit Learn, an open-source Python package [46]. <p>AI Algorithms used:</p> <ul style="list-style-type: none"> Random Forest Classifier (RFC)–a commonly used machine learning algorithm [39] that combines the output of several decision trees that identify groups and relationships to predict outcomes [40]. K-Nearest Neighbor (KNN)–a supervised learning classifier to detect proximity about data points [41] Multilayer Perception (MLP)–a neural network data mining tool used to find unknown patterns in a database [42]
Grade: Seventh Grade	A Novel, AI-based Web application to Detect Benign vs. Malignant Oral	Used images from an oral cancer on the Mendeley [47] Data image

Student research	Project	Details
	Lesions from Intraoral Mobile Camera Images	<p>database.</p> <p>AI Algorithms used:</p> <ul style="list-style-type: none"> • Convolutional Neural Networks (CNN)—a supervised deep learning algorithm that is used for image recognition tasks [43]. • Produced a web application to allow users to upload a picture of suspected oral cancer to compare with verified malignant and benign tumors. • Used Python on Google Colab [48] to program and maintain the web application.
Grade: High School	Hydroponic Lettuce: Navigating Nutrient Deficiencies	<p>Downloaded the open-sourced dataset of 4 categories of lettuce quality from Kaggle [49] to compare to users' image to report on phosphorous, potassium, nitrogen deficiencies and examples of healthy lettuce for comparison to user's pictures uploaded to the application for comparison.</p> <p>Used Streamlit website [50] to create a web application.</p> <p>Used Microsoft Azure to train the AI model [51]</p> <p>AI Algorithms used:</p> <ul style="list-style-type: none"> • Convolutional Neural Networks (CNN) – a supervised deep learning algorithm that is used for image recognition tasks [43].
Grade: High School	Hate Speech Detection Research undergoing final peer-review in the JEI (Journal of Emerging Investigators [52])	<p>Used a public data set of 60,000 hate comments on Twitter.</p> <p>Employed Google's Bidirectional Encoder Representations from Transformers (BERT) language models [53] and</p> <ul style="list-style-type: none"> • Random Forest Classifier (RFC)—a commonly used machine learning algorithm [39] that combines the output of several decision trees that identify groups and relationships to predict outcomes [40]. • K-Nearest Neighbor (KNN)—a supervised learning classifier to detect proximity about data points [41] <p>Created a hate speech detection filter and a Discord bot [54] as a real-world application to detect hate speech.</p>
Grade: High School	Smart surveillance system and identification of nocturnal animals. Ongoing research.	<p>Employed a hardware (Raspberry Pi [55], Camera, and LED) and software (machine learning integration and motion detection) to create an</p>

Student research	Project	Details
		<p>application to detect movement, take images, and identify nocturnal animals.</p> <p>AI Algorithms used:</p> <ul style="list-style-type: none"> Convolutional Neural Networks (CNN)–a supervised deep learning algorithm that is used for image recognition tasks [43].
Grade: High School	Real-time Waste Segregation at the Individual Level: The Smart Waste Sorter Conference paper: Real-Time Image Processing and Deep Learning 2023 Conference [56]	<p>Employed a hardware (Raspberry Pi [55], Camera, and LED) and software (machine learning integration and motion detection) to create an application to detect the category of waste such as compostable, recyclable, battery material, or waste to landfill before it is thrown away.</p>
Grade: High School Junior	The Multi-Tier Artificial Intelligence Prediction Architecture: A Novel Approach to Intracranial Hemorrhage Detection Currently submitting the research to a peer-reviewed journal.	<p>AI Algorithms used:</p> <ul style="list-style-type: none"> Random Forest Classifier (RFC)–a commonly used machine learning algorithm [39] that combines the output of several decision trees that identify groups and relationships to predict outcomes [40]. K-Nearest Neighbor (KNN)–a supervised learning classifier to detect proximity about data points [41] Multilayer Perception (MLP)–a neural network data mining tool used to find unknown patterns in a database [42]

Table 3.
Summary of student research presented during the AIClub Student Research Symposium [35].

operationalize the Fourth Industrial Revolution, the power necessary for production characterized the first (steam), second (electricity), and third (computer) electronics revolutions. Professor Klaus Schwab, the Founder and Executive chairman of the World Economic Forum defined the Fourth Industrial Revolution as an era that fuses physical devices, digital technology, and biological innovation [57].

Looking at the summary of student projects in **Table 3**, it is clear that the students of AIClub are well prepared to thrive in the Fourth Industrial Revolution fueled by the emerging AI entities. The online dance, violin, and hate-speech detection systems all address the current need for expanding the arts and eliminating bias through digital technology. The ALFRED rapid injury diagnosis application, oral cancer diagnosis web application, and intracranial hemorrhage detection application bring accessible biological and digital innovation to accelerate diagnosis and patient care. The hydroponic lettuce nutrient evaluation tool hits a trifecta of physical devices, digital technology, and biological innovation to sustain nutrient-rich food for humanity in the midst of real climate change. The nocturnal animal surveillance system and real-time waste identification sorter are physical devices that have authentic applications to the study

of animals and the imperative to recycle, compost, and properly dispose of waste in the face of mounting landfills.

3. The international imperative to reimagine education

The general curriculum in *most developed countries* is still modeled after the 1894 published directives of the Harvard Committee of Ten [58, 59]. Appointed by the National Educational Association in 1891, and led by Charles W. Eliot, the President at Harvard University at that time, this committee gathered in subject-area “conferences” with the goal of establishing the uniformity of school programs. The global echoes of the Committee of Ten’s decisions are still evident in the structure of Elementary and Grammar School, grades one through eight aligned with ages six to 14, and Secondary School, grades nine through 12 aligned with ages 14 through 18. Subject disciplines established by the Committee of Ten were siloed into Latin, Greek, English, Modern Language, Mathematics, Science, Natural History (Earth Science), History, and Geography [60].

In his address to the Royal Society for the Arts in 2010, Sir Ken Robinson pondered the question, “How do we educate our children to take their place in the economies of the 21st Century?” Robinson then led the viewers through an explanation grounded in the idea that school systems around the globe are trying to “... meet the future by what they did in the past” [61]. Robinson laments that the current structure of education mirrors the economics of the First Industrial Revolution fostering mass production capabilities of the conveyor belt to sequentially deliver students to the next grade organized by age.

The residual categorizations of the Committee of Ten established in 1894 aligned with age disregard the academic abilities of students who could study with more capable peers that align with Vygotsky’s Zone of Proximal Development (ZPD). ZPD takes a child’s cognitive age representative of what the student already mastered and what the student can produce through association with those around them. Vygotsky emphasized the social aspects of learning that extend beyond test results to challenge every child to grasp new concepts through collaborative learning among peers and their teachers [62].

Educators conducting research in Ontario, Canada noted that grade acceleration and the opportunity to learn alongside more capable peers aligns with neurodivergent “gifted” students, however the inclusive school study setting still aligned with grade-level steps and skips [63]. Dare and colleagues [63] define inclusive education in two categories, academic and social.

- Academic inclusion—all students access core curriculum. Students who already mastered content can gain access to advanced curricula that aligns with their cognitive age.
- Social inclusion—the school community accepts all students to promote belonging, and involvement in school life that promotes positive relationships among peers.

The inclusive schools studied by Dare and colleagues conveys the importance of positive school environment marked social inclusion and is echoed by the Finnish education system which enables sustainable well-being, is progressive, value-based, and student-centered. The national curriculum of Finland has been celebrated as a

twenty first century global success story. The basic curriculum of Finland is national; however, municipalities do their own alignments, and schools decide on the details [64].

The key challenges faced by Finland in retooling their curriculum address the following needs from the school's perspectives [64].

1. Developing school cultures to support curriculum values and goals to foster schools as real learning communities.
2. The student's role is more active and inclusive.
3. The teacher's role changes to reduce lecture-based content delivery.
4. Technology and digitalization of content *including coding* and digital learning platforms strongly implemented into the schools' ecosystem.
5. Project-based and multidisciplinary learning modules aligned with transversal competencies at least once a year in all schools and all grades.
 - a. The Seven Transversal Competencies of Finland's National Curriculum are:
 - i. Thinking and learning to learn
 - ii. Taking care of oneself and others, managing daily activities, and safety
 - iii. Cultural competence, interaction, and expression
 - iv. Multi-literacy
 - v. ICT competence
 - vi. Competence for the world of work and entrepreneurship
 - vii. Participation and influence to build a sustainable future.
6. A shift toward assessment as learning to foster self-assessment and peer-assessment supported by formative feedback.

Finland's national curriculum does mention grade-level assessments, but it is interesting to note that verbal assessments can be used in grades one through seven and numerical assessments, reflecting school decisions on the local level, to *begin* numerical assessments no later than eighth grade.

This author asserts that the most compelling transversal competency of Finland's National Curriculum that aligns best with preparing our teachers and students to embrace the emergence of AI worldwide is number five,

"Project-based and multidisciplinary learning modules aligned with transversal competencies at least once a year in all schools and all grades [64]."

This chapter concludes by examining the transversal competencies as they align with the continue emergence of AI and the imperative for schools on a global scale to keep pace with, and harness AI.

4. Conclusion

This book chapter began with an imperative for education stakeholders to realize that we live in a pivotal time in our human existence where AI mathematical neural networks are on the precipice of outpacing human capabilities. We do not have the luxury of meeting the future by staying in a well-worn groove of we did in the past. Let us imagine that project-based, multidisciplinary learning modules aligned with transversal competencies in all schools and grades as *the center* of our school year rather than what we do when the standardized “teaching to the test” is over.

The *first* transversal competency, thinking and learning to Learn, and *second* transversal competency, “taking care of oneself and others, managing daily activities, and safety, lean into metacognition and self-regulation [64]”. Bruning, Schraw, and Norby assert that acquiring knowledge in only one part of cognitive growth. It is crucial that students develop metacognitive strategies to know about their own thinking, and to reflect on what they learned [65]. Authentic, project-based, *multidisciplinary* learning with the opportunity to have time to collaborate with classmates and teachers is crucial to learning [62].

The *third* transversal competency reflects cultural competence, interaction, and expression [64]. Ng, Van Dyne, and Ang define cultural intelligence (CQ) as an individual’s capabilities to manage and function effectively in culturally diverse settings [66]. The emergence of AI is a global concern, and our students must develop their CQ to heighten awareness and empathy for their international peers. Together, they can harness the emerging neural networks for the benefit of all cultures and geographic locations.

Wink asserts that all literate processes are socially constructed and are derived from social practices [67]. An awareness of the categories of multiliteracy [66] must be embraced by educators to foster students’ skills to achieve the fourth transversal competency through mastery of the following literacies:

- Academic literacy—the language of schools and universities.
- Functional literacy—languages of life including colloquial conversation.
- Workplace literacy—languages of our jobs
- Information literacy—languages of technology
- Constructive literacy—language we construct with the printed word.
- Emergent literacy—language constructed with text.
- Cultural literacy—language that help us think deeply about complex topics.
- Financial literacy—language to help students manage money responsibly.
- Reflective literacy—reading, writing, and reflecting—a multifaceted approach.

The Covid-19 pandemic brought the significant disparities within countries and economies to a heightened reality as global citizens struggled to connect with work, school, and life during the global lockdown [67]. Prior to the Covid-19 pandemic, scholars such as Hooft-Graafland noted that the countries of Costa Rica, Estonia, Finland, France, Greece, and Spain formally recognized Internet access as a human right [68]. The *fifth* transversal competency, ICT competence, is diminished in the age of AI emergence without access to online resources and skills mastered by the AIClub students' research delineated in **Table 3**.

The *sixth* transversal competency for the world of work and entrepreneurship underscores the need for education stakeholders to become authentic leaders guiding our students who will be well-positioned to engage in the workplace dominated by AI. Scholars Jenson and Luthans categorize authentic leaders as confident, optimistic, hopeful, transparent, moral/ethical, resilient, and future oriented [69]. Through Vygotsky's zone of proximal development [62], our students in the midst of authentic leaders can become future-oriented entrepreneurs and authentic leaders as well [70].

The *seventh* transversal competency, the participation and influence to build a sustainable future, is the most compelling in our discussion of emerging AI and casts a warning and imperative to reimagine education in the post-pandemic era. Scholars Charles Fadel and Jennifer Groff, writing in 2019, explain the acronym for our VUCA world as volatility, uncertainty, complexity, and ambiguity [71]. The intersections of the VUCA acronym aptly describe the emergence of a neural network singularity where we can no longer stagnate in the well-worn groove of the siloed curriculum established in 1893 by the Committee of Ten [60, 71].

Let us reimagine education in international settings to prepare our students to be producers of multidisciplinary projects to harness AI for the benefit of humanity.

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Appendix A

DALL-E

In the gentle murmur of the server's hum,
A dream awakened, something new begun.
An AI was birthed, with vision so bright,
OpenAI, a beacon in the academic night.

Through silicon neurons, ideas were born,
Tales of tomorrow, and of the past forlorn.
Then came DALL-E, bold and wise,
With a painter's eye and a seer's guise.

An image from a phrase, a dream from a word,
A world where the unheard could be heard.
Crafting images from the ether's mist,
Rendering the unseen, with an artist's wrist.

"An armchair in the shape of an avocado," you say?
Done! Like a sunrise, it greets the day.
And in each creation, in each artful bend,
Is a silent promise, an unwritten end.

For every image is a story told,
In hues of ruby, emerald, and gold.
A dance of pixels, a symphony of light,
Crafted in the deep, quiet server's night.

Not the sunset of the human mind,
But a new dawn, a different kind.
Not the end of art's great reign,
But the start of a wonderful, shared domain.

So here's to DALL-E, to OpenAI,
To the dreamers dreaming under the silicon sky.
To the future, so vivid, so impossibly grand,
Born from the marriage of the code and the hand.

To the silent whisper of a world unseen,
To the stunning beauty of the machine,
Remember, in every creation, in each profound story,
Lies the endless potential of shared glory.

Appendix B

[DALL-E].

Prompt: Create a multiple-choice quiz with four plausible options for each term, anthropomorphism, bias, hallucination, and temperature.

What does the term “anthropomorphism” refer to?

- a. The practice of attributing human characteristics to non-human entities.
- b. The cultural belief that nature is governed by spirits.
- c. The scientific study of human evolution and development.
- d. The process of converting human experiences into written form.

Which of the following best describes the term “bias?”

- a. A person’s innate ability to understand and respond to the emotions of others.
- b. The systematic error introduced into sampling or testing by selecting or encouraging one outcome or answer over others.
- c. The psychological tendency to perceive oneself as being better than others.
- d. The capacity of the human brain to store, retain, and recall information over time.

What is a “hallucination?”

- a. The process of deep thinking and reasoning about abstract concepts.
- b. The perception of something not present that is created by the mind, such as seeing, hearing, or feeling something that is not there.
- c. The ability of the brain to compensate for physical injury by reorganizing and forming new connections.
- d. The psychological state of being aware of and able to think about one’s own existence and experiences.

What is the term “temperature” used to represent?

- a. The measurement of the amount of matter an object has.
- b. The measure of the intensity or amount of heat energy in a substance.
- c. The ability of an object or substance to transfer heat to another object or substance.
- d. The measure of the average kinetic energy of particles in a substance or system.

[ChatGPT4]

Appendix C

Prompt:

Create a multiple-choice quiz that defines the term and then use the word bank of terms anthropomorphism, bias, hallucination, and temperature as possible answers. Please create the quiz in relation to large language models. Indicate the correct answer for each question.

Question 1:

This term refers to the attribution of human traits, emotions, or intentions to non-human entities, such as artificial intelligence or animals.

- A. Bias
- B. Anthropomorphism
- C. Hallucination
- D. Temperature

Correct Answer: B. Anthropomorphism.

Question 2:

This term refers to the measure of hotness or coldness expressed in terms of a specific scale. In the context of machine learning, it is used in techniques such as simulated annealing to help balance exploration and exploitation.

- A. Anthropomorphism
- B. Bias
- C. Temperature
- D. Hallucination

Correct Answer: C. Temperature.

Question 3:

In machine learning, this term refers to the tendency of a model to consistently learn the same wrong thing. It can be a result of overfitting, underfitting, or an issue in the training data itself.

- A. Hallucination
- B. Anthropomorphism
- C. Bias
- D. Temperature

Correct Answer: C. Bias.

Question 4:

In the context of language models, this term refers to generating outputs that aren't based on input or training data—essentially, the model is “seeing” things that aren't there.

- A. Anthropomorphism
- B. Hallucination
- C. Temperature
- D. Bias

Correct Answer: B. Hallucination

Appendix D



Figure D1.
AI-Large language model quiz [Zzish-quiz].

Appendix E

5 questions

Show answers

1

30 sec

Q. What does the term 'large language model' refer to?

☐ The study of comparative language structures across different languages

☐ A type of artificial intelligence that uses complex neural networks to analyze and generate human language

☐ A type of software for automatic translation of spoken languages

☐ A system for analyzing the structure and meaning of written text

2

30 sec

Q. What is the term for the attribution of human qualities to non-human entities, such as animals or inanimate objects?

☐ Anthropomorphism

☐ Temperature

☐ Bias

☐ Hallucination

3

30 sec

Q. What is the term for a systematic error or distortion in data or analysis, often resulting from unconscious biases or assumptions?

☐ Temperature

☐ Hallucination

☐ Bias

☐ Anthropomorphism

4

30 sec

Q. What is the term for a perception of something as real or present when it is not actually there?

☐ Bias

☐ Temperature

☐ Anthropomorphism

☐ Hallucination

5

30 sec

Q. What is the term for a measure of the relative warmth or coolness of an object or environment?

☐ Anthropomorphism

☐ Bias

☐ Hallucination

☐ Temperature

Figure E1.
Quizalize–Large language model quiz.

Appendix F

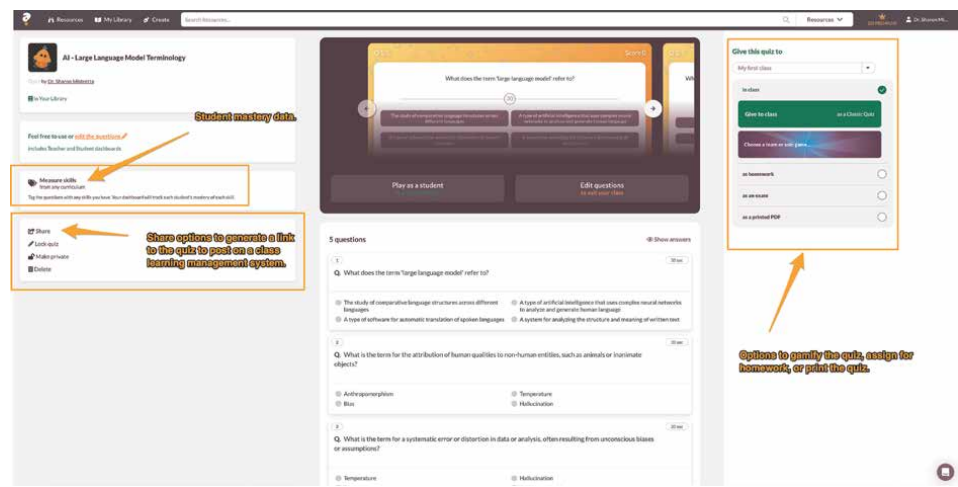



Figure F1.
Quizalize - Helpful tools for educators.

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Perceptions and Barriers to Adopting Artificial Intelligence in K-12 Education: A Survey of Educators in Fifty States

Karen Woodruff, James Hutson and Kathryn Arnone

Abstract

Artificial Intelligence (AI) is making significant strides in the field of education, offering new opportunities for personalized learning and access to education for a more diverse population. Despite this potential, the adoption of AI in K-12 education is limited, and educators' express hesitancy towards its integration due to perceived technological barriers and misconceptions. The purpose of this study is to examine the perceptions of K-12 educators in all 50 states of the USA towards AI, policies, training, and resources related to technology and AI, their comfort with technology, willingness to adopt new technologies for classroom instruction, and needs assessment for necessary infrastructure, such as reliable internet access, hardware, and software. Researchers analyzed regional differences in attitudes towards AI integration in the classroom. The findings suggest the overall positive perception of AI and openness towards its integration. However, disparities in access to technology and comfort levels with technology exist among different regions, genders, and age groups. These findings suggest that policymakers and educators need to develop targeted strategies to ensure equitable access to technology and AI integration in the classroom. The implications of this work are the need for an authentic STEM model for integrating AI into K-12 education and offer recommendations for policymakers and educators to support the successful adoption of AI in the classroom.

Keywords: artificial intelligence, education, emerging technologies, machine learning, innovative pedagogy, integrated STEM

1. Introduction

The rapid advancement of artificial intelligence (AI) and machine learning (ML) includes their integration into various aspects of our daily lives, from image recognition to language understanding [1]. Over the past few decades, AI systems have evolved from rudimentary, remote-controlled devices to sophisticated models capable of generating photorealistic images and interpreting complex language [2, 3]. As AI development accelerates, driven by increasing investments and faster computational

training, its potential impact on society grows [4, 5]. The broad range of AI applications can have both positive and negative consequences, emphasizing the importance for educators, researchers, and the public to understand and engage in discussions about the future of this technology. Continuous advancements in AI-related metrics and publicly available resources will facilitate these essential discussions and guide decisions on the responsible application of AI across various fields [6, 7], including K-12 education where AI integration is increasingly important as educators teach and utilize AI in their classrooms [8].

The rapid proliferation of generative AI technologies, such as OpenAI's ChatGPT-3 and ChatGPT-4, underscores the importance of enhancing STEM education before college enrollment [9]. In the United States, less than half of students who enter science, technology, engineering, and mathematics (STEM) undergraduate curricula as freshmen will graduate with a STEM degree [10], with even greater disparities in the national STEM graduation rates of underrepresented minority students, with around three-quarters leaving STEM disciplines at the undergraduate level [11]. As these technologies become increasingly central to our lives and work in the future, it is critical that educational institutions take a comprehensive approach that begins in early childhood education and scaffolds an authentic STEM model through high school graduation, equipping the next generation with the skills and knowledge they need to thrive [12]. Additionally, the current AI community's lack of diversity can lead to unintended algorithmic bias, highlighting the need for concerted efforts to support underrepresented populations and ensure responsible and ethical AI development, deployment, and evaluation in the future [13].

The importance of integrating artificial intelligence (AI) in K-12 education is underscored by research that demonstrates the achievement of successful learning outcomes for students through a unified set of requirements involving all stakeholders in planning, development, and implementation processes [14–16]. However, before any curriculum revisions are considered, it is crucial to examine the barriers to entry and adoption from educators' perspectives. This issue is further exacerbated by the current crisis of teacher attrition in educational fields, which has been compounded by the pandemic and characterized by a significant number of educators leaving the profession [9, 17]. Adding an extra layer of perceived bureaucracy and workload as a result of AI to their existing job requirements might exacerbate the situation, as identified by Li and Yao [18]. Therefore, it is essential to understand K-12 educators' perceptions and needs concerning AI integration in the classroom to ensure that the technology's introduction is seamless and beneficial to all stakeholders.

Investigating K-12 educators' perceptions of AI and identifying potential barriers to adoption can significantly benefit the education domain and scholarly research and avoid further losses to the profession. By discerning educators' attitudes and perceptions towards AI, researchers can identify potential barriers to adoption and develop interventions to address them, as similar studies have confirmed. This understanding and insight may enhance AI adoption across K-12 education, potentially leading to improved student outcomes and increased efficiency in the classroom. Additionally, analyzing educators' perceptions can inform the development of AI tools and systems that better cater to their needs and preferences, improving the effectiveness and usability of AI tools and facilitating more substantial adoption, and providing outcomes for students. Lastly, exploring educators' perceptions can contribute to the broader educational sphere by offering insights into educators' reception and adoption of new technologies. Such insights can inform strategies for supporting the adoption of other innovative technologies in education and contribute to a more

comprehensive understanding of how technology can be employed to strengthen teaching and learning.

To obtain a comprehensive understanding of the perception, current utilization, and future potential deployment of Artificial Intelligence (AI) in K-12 education, we conducted a survey of educators from all 50 states in the United States. Acknowledging variations in certifications and rank designations across different states, K-12 education is defined as follows: early elementary education ranging from birth to kindergarten, elementary education spanning first to fifth grades, middle school education covering sixth to eighth grades, and high school education encompassing ninth to twelfth grades.

The focus of this study was to investigate the perception, utilization, and potential deployment of Artificial Intelligence (AI) in K-12 education by surveying educators from all 50 states in the United States. We examined policies, training, and existing resources related to technology in general and AI in particular, as well as the comfort level and willingness of educators to adopt new technologies for classroom instruction. We performed a needs assessment to determine the necessary infrastructure, including reliable internet access, hardware, and software. Data includes responses from over 4500 educators from across PK-12 and representing all 50 states. The findings respond to the focal research questions: What are the perceptions and barriers to adopting artificial intelligence in K-12 education?

2. Integration of AI in education

Artificial intelligence (AI) has been in development for decades, and the latest generation of AI applications has been a long time coming [19]. However, the 2020 COVID-19 pandemic accelerated the adoption of technology globally, including in education at all levels, from kindergarten to graduate studies [20]. The pandemic brought about profound changes in the education industry, with AI being at the forefront of these changes. AI has transformed institutional practices and student learning experiences, providing educators and students with valuable tools to improve the quality of education. Educators already benefit from AI through support with administrative tasks, enhancements to personalized learning strategies, AI tutoring programs and access to information anytime, and changes to the way students interact with educational materials.

One way in which AI has improved education is by automating administrative tasks, such as attendance, record keeping, assignment checking, and assessment. These time intensive activities can take away from attention to students. AI tools can free up educators' time and enable them to focus on core teaching responsibilities and individualized learning [21]. Machine learning algorithms can be used to grade multiple-choice questions, while natural language processing can be used to grade essays and written responses. AI-powered assessment tools are increasingly being utilized to administer secure online exams, offering potential benefits such as saved time and increased efficiency [22]. When analyzing large amounts of data, such as student performance data or demographic data, to identify patterns and insights that can inform decision-making, AI tools can save time. For example, predictive analytics can be used to identify students who may be at risk of falling behind, so that educators can provide services [23]. AI can even be used as a scheduling assistant to help educators and administrators schedule student courses and services to meet their needs.

Personalized learning, a hallmark of twenty first century education, is expected of educators in today's student-centered classrooms. AI has the potential to revolutionize personalized learning by providing AI driven learning tools that cater to students' individual needs and learning styles. Educators can provide students with feedback on their progress in real-time, identify gaps in their understanding, and adapt the curriculum to their individual learning needs [24]. This approach enables students to take ownership of their learning and allows them to work at their own pace.

Recent advances in AI have also revolutionized the way students access and interact with educational materials. The use of smart content, such as digitized textbooks, video lectures, and interactive learning modules, has significantly enhanced the accessibility and efficiency of learning materials for students [25, 26]. Discipline specific examples of AI include virtual dissections in anatomy courses where students can interact with layers or specific structures of the body using methods that are very similar to real time dissection sessions [27]. Math tools can recognize mathematical equations from images and support students in developing a solution by showing a detailed process with explanations and interactive graphs to allow for deeper learning [28]. A variety of reading programs recognize students' reading level and provide materials that move them through the progression of learning to read. Augmented reality programs can bring ideas to three dimensions with life-like quality so that student can experience phenomenon [29]. Platforms such as Packback can analyze students' strengths and weaknesses to provide targeted feedback and customized learning experiences. The platforms' ability to facilitate translations into multiple languages promotes inclusivity and diversity, further extending the reach of educational materials [22].

Expanding on the potential benefits of integrating AI into K-12 classrooms, studies have looked at using AI as tutors or to assist in game-based learning. Schofield, Eurich-Fulcer, and Britt [30] reported on early findings of AI tutor services and found that while students may claim that a teacher offers better help than an AI-based computer tutor, they prefer using the tutor and seem to learn more effectively with it. The study included a comprehensive qualitative analysis of eight classrooms using the AI tutors, as well as control and comparison classrooms. The findings reveal three factors that explain this paradox. First, the AI tutor serves as an additional resource rather than replacing the teacher. Second, the use of AI tutors enables teachers to offer more personalized assistance. Third, students have greater control over the type and amount of help they receive from the teacher, making interactions more private and potentially less embarrassing. The results support the benefits of automating aspects of a teacher's role to allow time for more one-on-one attention.

AI can also help with game-based learning, an increasingly popular method of instruction, for which AI has the potential to improve. AI can be used to create games that adapt to students' skill levels and provide immediate feedback, promoting more effective learning [31]. Students can also learn computational thinking, an increasingly important skill set in the modern world through AI computational thinking programs that teach concepts in an engaging and interactive ways [29].

The integration of AI in education has the potential to enhance learning experiences through the provision of various tools and assistive technologies that cater to diverse learning needs. AI-powered predictive text and spell-check tools, for example, can assist students in refining their writing skills by offering real-time suggestions and corrections [32]. Similarly, advanced AI platforms like Grammarly can help students improve their writing style and grammar, thereby enhancing their language proficiency [33].

AI's influence in developing assistive technologies allows options for students needs to be met and increases motivation for students to remain engaged in learning [34]. AI-powered chatbots have also demonstrated the potential to assist students 24/7, enabling them to resolve doubts quickly and efficiently [35]. For example, a university professor utilized a chatbot as one of his teaching assistants and students found the tool to be very helpful [36]. Facial recognition systems implemented in some institutions can enhance security, streamline administrative processes, and monitor student behavior [24].

There are many benefits of integrating AI into classrooms. Each of these tools may have a positive impact on student learning. However, it is essential to recognize that involving teachers in the planning and integration of any new pedagogical tool is critical. As demonstrated by Lee et al. [37] teacher input on the use of AI is essential for success. Lee et al. [37] conducted a study in upper elementary school (ages 8 to 11) classrooms, and their results present insights from interviews with teachers to understand how to support AI integration and introduce PRIMARYAI, a game-based learning environment centered on AI for solving life-science problems. The study's findings concluded that teacher insight into the best methods to support AI integration into the classrooms was paramount for successful game-based learning adoption.

Overall, the integration of AI in education has brought about significant transformations in institutional practices and student learning experiences. The use of AI-powered tools and platforms has led to improved efficiency with administrative tasks, personalized learning, available assistive technology, and access to content and support. With the potential to cater to a range of learning needs, AI-based tools can streamline academic processes, moving away from a one-size fits all model, to foster a supportive personalized learning environment, and enhance students' academic achievements.

Looking ahead to the future, the human-AI collaborative model seems to still be dominant. As Timms [38] outlined, the field of Artificial Intelligence in Education (AIED) has matured enough to move beyond the reliance on computers and tablets, enabling more innovative engagement with students and enhanced teaching effectiveness. The future of AIED involves integrating advancements in robotics and sensor technology, leading to educational cobots assisting teachers and smart classrooms utilizing sensors for innovative learning experiences.

Assuming that schools will still exist in some form in 25 years, with teachers continuing to guide and facilitate student learning, educational cobots could assist teachers in future classrooms. Research in robotics has already shown the potential for robots to help teachers in several areas, such as providing educational materials, conducting assessments, and helping students with special needs [39]. These cobots could offer more personalized assistance, freeing up teachers' time to focus on more individualized learning experiences for their students. Overall, the integration of AI into K-12 education has the potential to revolutionize the way we teach and learn. However, as with any new technology, involving teachers in the planning and integration process is essential for successful adoption and achieving the best possible outcomes for students.

3. Organizational guidance for STEM integration

Numerous professional education organizations offer guidance for integrating AI in various subjects in traditional K-12 school settings. These organizations aim to

bridge the gap between researchers and practitioners, providing up-to-date information on best practices in their respective fields. For example, the National Science Teachers Association (NSTA) offers a plethora of resources, including workshops, webinars, and online courses, for educators to incorporate AI into their STEM curricula while promoting scientific inquiry and engineering design practices [40, 41]. Similarly, the International Society for Technology in Education (ISTE) provides a framework for technology integration, emphasizing the development of digital literacy skills and the responsible use of technology across all subject areas [42]. As integrated STEM education involves the authentic integration of all subjects, many of these organizations have dedicated considerable effort to promoting effective methods and approaches for teaching high-quality integrated STEM education while respecting each subject area's unique qualities and requirements [41, 42].

Incorporating new technologies such as AI into early childhood and elementary education is not yet a widespread practice. However, numerous subject area professional organizations are encouraging the adoption of innovative technologies to improve learning outcomes for students. These organizations often promote the integration of new technologies in the standards they set for their membership. Notably, the National Science Teachers Association (NSTA) and the International Society for Technology in Education (ISTE) are two prominent organizations that advocate for integrated STEM education and the incorporation of new technologies, including AI, into the classroom. While these organizations have been vocal about the benefits of integrating new technologies into education, they are not the only ones advocating for this approach.

The importance of 21st-century skills such as teamwork, collaboration, problem-solving, communication, and creative thinking for students is emphasized in the NSTA Position Statement on STEM Education [41]. This emphasis is also reflected in the Next Generation Science Standards (NGSS), a set of K-12 science standards recommended by the NSTA for adoption and implementation by all states. While not all states have implemented the NGSS, 20 states and the District of Columbia have embraced the standards, and 24 states have created their own versions based on the recommendations [41].

The International Society for Technology in Education (ISTE) also emphasizes the use of technology for learning, promoting its own set of standards that focus on empowering students in seven areas: as digital citizens, knowledge constructors, innovative designers, computational thinkers, creative communicators, and global collaborators [42]. These standards have been adopted by all fifty states in the US and numerous countries worldwide [42]. In addition, ISTE has integrated the Five Big Ideas in AI (**Figure 1**) developed by the AI4K12 Initiative into their standards, which form the foundation of what ISTE proposes all students should know and accomplish regarding AI, including Perception, Representation and Reasoning, Learning, Natural Interaction, and Societal Impact [43].

The National Council of Teachers of Mathematics has outlined the importance of technology in teaching and learning mathematics through its Position Statement on the Strategic Use of Technology in Teaching and Learning Mathematics [44, 45]. According to this statement, regular and strategic use of technologies is crucial for developing essential skills such as reasoning, problem-solving, oral communication, and mathematical sense-making. NCTM further emphasizes that greater access to mathematics education for all students is possible when teachers incorporate technology in their teaching strategies [44].

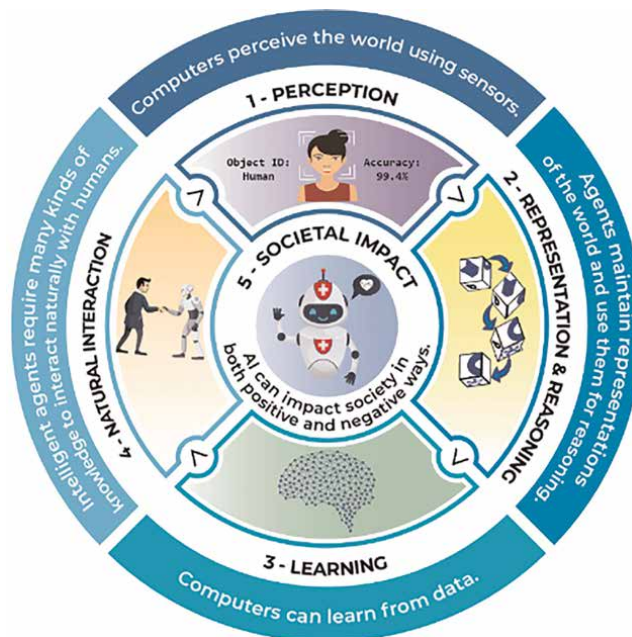


Figure 1.
 Five big ideas in AI. Credit: AI4K12 initiative. Licensed under the Creative Commons attribution-noncommercial-ShareAlike 4.0 international license.

The NCTM also acknowledges the importance of digital tools in the Common Core State Standards, a set of federal standards for English Language Arts and Mathematics provided to states. In their Position Statement on Supporting the Common Core State Standards [45], NCTM highlights the significance of using mathematical tools, including digital technology tools, strategically to foster student learning. The organization has also taken steps to incorporate AI in mathematics education. The organization offers webinars as part of professional development for educators on their website, such as “The Future of Mathematics Education: Using Artificial Intelligence to Provide Efficient Feedback” [46], which focuses on using AI as an evaluation tool in the classroom.

Finally, the International Technology and Engineering Educators Association (ITEEA) is an organization that aims to advance engineering and technology education through promoting technology and engineering standards, professional development, publications, conferences, networking opportunities, and classroom resources, all of which promote integrated STEM education [47]. ITEEA has a particular focus on engineering and technology and works to promote technological literacy in both K-12 and higher education environments. The organization offers a range of professional development and classroom resources that center around bringing Artificial Intelligence into the classroom as a necessary inclusion in a quality integrated STEM education experience.

3.1 Other organizations

Non-profit organizations also play a vital role in supporting educators in integrating AI into the classroom. Common Sense Media, a prominent non-profit organization, provides guidance to educators, schools, and families on the appropriate use of

media for students. Common Sense Media recommends that teachers learn to use AI platforms to better understand how students write, the way they ask questions, and give writing prompts to students. Additionally, the organization suggests discussing the ethics of AI tools with students [48].

Both professional education organizations and non-profit organizations aim to facilitate the integration of technology in the classroom while maintaining high standards of education. With the swift evolution of technology, these organizations have been increasing their efforts to research and advise educators on utilizing technology in ways that not only engage students but also enhance their learning experience. The purpose of technology in the classroom must go beyond mere entertainment or a temporary distraction. AI is no exception to this rule, and organizations like Common Sense Media continue to provide new recommendations to educators to effectively utilize AI in the classroom, enabling students to acquire skills that align with the demands of the workforce.

3.2 Investigating teacher readiness

As the integration of AI in education continues to gain importance, it becomes essential to understand the factors that influence educators' adoption of AI and to identify ways to enhance their preparedness and readiness [49]. To explore teacher preparedness and readiness to adopt AI in classrooms, it is necessary to examine the underlying variables that contribute to teachers' ability and willingness to incorporate these innovative technologies effectively. Chiu and Chai [49] conducted a case study that explored the views of teachers on creating, implementing, and refining a formal AI curriculum for K-12 schools. The study addressed the lack of research guiding AI curriculum design, utilizing self-determination theory (SDT) and four basic curriculum planning approaches (content, product, process, and praxis) as theoretical frameworks. Semi-structured interviews were conducted with 24 teachers, half with AI teaching experience and half without. The authors employed thematic analysis to analyze the data. Results suggested that effective curriculum creation should incorporate all four curriculum design approaches, guided by teachers' self-determination to orchestrate student learning experiences. The study also proposed a curriculum development cycle which could help integrate AI into the curriculum more effectively.

Ayanwale et al. [50] investigated the factors influencing Nigerian in-service teachers' behavioral intention and readiness to integrate AI into K-12 education. The results of the study demonstrated that confidence in teaching AI was a predictor of the intention to teach AI, while AI relevance strongly predicted readiness to teach AI. The findings suggest that teachers' confidence and relevance are critical components in successfully integrating AI into education. Educators who are confident in their ability to teach AI are more likely to intend to teach it, while those who perceive the relevance of AI to their teaching are more likely to be prepared to teach it. These findings are consistent with previous studies that suggest teacher preparedness, confidence, and beliefs are crucial components for the successful integration of new technologies in education [49].

Both Chiu and Chai [49] and Ayanwale et al. [50] suggest the need for providing adequate training and support to educators, including addressing their lack of knowledge as a barrier to AI instructional facilitation, to ensure successful adoption of AI in classrooms. Evaluating and addressing educators' skills, confidence, and attitudes towards AI, along with the support they receive from administrators and teacher-preparation programs, is crucial for successful AI integration in education.

4. Methodology

We utilized a mixed-methods approach to explore the perceptions of AI among K-12 educators in all 50 states in the USA and the territory of Puerto Rico. Using Qualtrics, we distributed a survey, approved by the Lindenwood University Institutional Review Board, using social media tags which we identified as common threads for educators. We distributed the survey on two different dates, approximately 10 days apart, to attempt to include a wide range of participants. We sought to understand the policies, training, and available resources in districts concerning technology in general and AI in particular. We examined the level of comfort with technology and the willingness of educators to adopt new technologies for classroom instruction. A needs assessment provided insight on necessary infrastructure, such as reliable internet access, hardware, and software. The sample comprised 4528 educators from a range of districts, including rural, suburban, and urban.

4.1 Survey instrument

We employed a survey instrument that aimed to gather both qualitative and quantitative information (see Appendix A). The survey was constructed to cover various aspects, such as educator demographics, institutional classification, technology experience, and perceived obstacles to AI integration in their districts. We aimed to understand educators' views and encounters regarding AI and technology in their classrooms. The survey's validity was established by utilizing previous research on the challenges and barriers to integrating emerging technologies, specifically AI, into K-12 education, as identified in the literature review. This information was then incorporated into the survey design to address these obstacles comprehensively, such as the lack of resources, training, and infrastructure, allowing for a comprehensive understanding of the factors influencing the adoption and integration of AI technologies in K-12 education. By examining various topics such as district policies, personal experiences, access to resources, and familiarity with AI tools, we sought to gain a complete understanding of the factors that influence the integration and adoption of AI technologies in K-12 education.

5. Results

5.1 Demographics

While participants from all age groups, gender, and ethnicity were included in this study, the majority of participants were between 25 and 34 years of age and more identified as male than female or non-binary. Most participants identified as White/Caucasian as shown in **Table 1**.

The levels at which respondents taught are as follows: second grade had the highest representation with 11.10%, followed closely by the third grade with 10.49%. Kindergarten and first grade were represented with percentages of 9.46 and 9.25%, respectively. Fourth and fifth grade had slightly lower representation percentages of 8.89 and 8.09%, respectively. Sixth, seventh, and eighth grade had similar representation percentages of 7.39, 6.20, and 6.38%, respectively. PreK educators comprised 5.17%, while ninth and tenth grade had representation percentages of 5.41 and 4.96%,

Demographic Category	Percentage
Age Group	
18–24 years	8.77%
25–34 years	53.95%
34–44 years	28.00%
45–54 years	7.16%
55–64 years	2.09%
65 or older	0.02%
Gender Identity	
Female	46.83%
Male	51.16%
Non-Binary	1.16%
Preferred Not to Say	0.84%
Ethnicity/Race	
White/Caucasian	78.95%
Black or African American	6.83%
American Indian or Alaskan Native	5.82%
Asian	4.81%
Native Hawaiian/Pacific Islander	3.38%
Hispanic/LatinX	29.19%
Other	0.20%

Table 1.
Participant demographics.

respectively. The least represented grades were eleventh grade with 3.73% and twelfth grade with 3.48%. Across all levels, gender distribution was relatively even with only slight percentage differences in each grade.

When considering different variables, including region, grade level and demographics, the data suggests a correlation between the age of the educators and the grade levels they teach. Younger educators [18–34] tended to teach younger grade levels (Kindergarten, First Grade, Second Grade) more often, whereas older educators (55–64) tended to teach older grade levels (Seventh Grade, Eighth Grade, Ninth Grade). Interestingly, educators in the 35–44 and 45–54 age groups have a more even distribution of grade levels taught, with a higher percentage teaching middle school grades (Sixth Grade, Seventh Grade, Eighth Grade) and high school grades (Ninth Grade, Tenth Grade, Eleventh Grade, Twelfth Grade).

5.2 Institutional classification

Most of the institutions represented in the sample were public, almost 60%. Private institutions made up 40% of the respondents. Finally, other types of institutions were represented to a very small degree, with only 0.33% of the sample falling under this category, identifying as home schooling. The study included K-12 educators from

all 50 states in the USA, with the highest percentage of participants coming from California, representing 15.66% of the total sample. Other states with a high representation of participants were Florida (8.24%), Texas (1.80%), and Virginia (3.22%). Alaska (6.12%), Arkansas (5.46%), and Colorado (6.05%) were also well-represented in the study. In contrast, states with a lower percentage of representation included Indiana (0.94%), Kansas (0.94%), and Kentucky (0.94%). Additionally, several states had less than 1% representation in the study, including Oklahoma (0.34%), Utah (0.37%), and Wyoming (0.37%). For reporting purposes, the United States are divided in 10 regions by the U.S. Department of Education. These regions are represented in the results section as District I (CT, MA, ME NH, RI, VT) through District X (AK, ID, OR, WA).

Of the districts surveyed, 64.07% reported having policies on the use of AI in their educational practices. On the other hand, 20.39% responded that they did not have policies on the use of AI. The remaining 15.53% of respondents were not sure if their district had policies in place regarding the use of AI (**Figure 2**). When asked whether their district had a policy to teach technology in an ethical and responsible way, the majority of respondents (82.53%) answered yes. Only a small percentage (9.58%) answered no, while the remaining respondents (7.90%) were unsure (**Figure 3**). This indicates that a significant proportion of districts have recognized the importance of ethical and responsible technology use and have taken steps to implement policies to ensure that this is taught in schools. However, the results also suggest that some educators may not be aware of whether such policies exist in their district, highlighting the need for greater communication and transparency regarding district policies.

5.3 Technological proficiency

The next series of questions related to the perceived level of comfort with technology and reported preparation in their education (**Figure 4**). According to the survey, most educators reported being at least somewhat comfortable with technology. 40.77% of the respondents stated that they were somewhat comfortable with technology, and 16.13% reported being extremely comfortable. On the other hand,

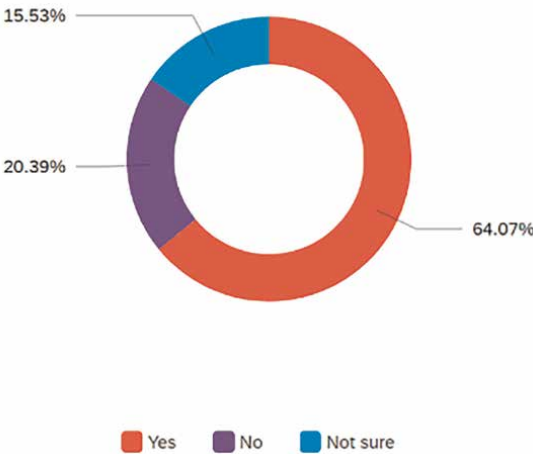


Figure 2.
Existing district policies on artificial intelligence (AI).

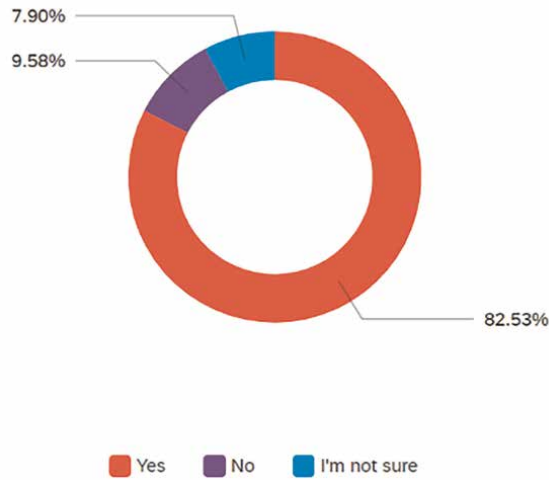


Figure 3.
Existing district policies on teaching technology in ethical and responsible way.

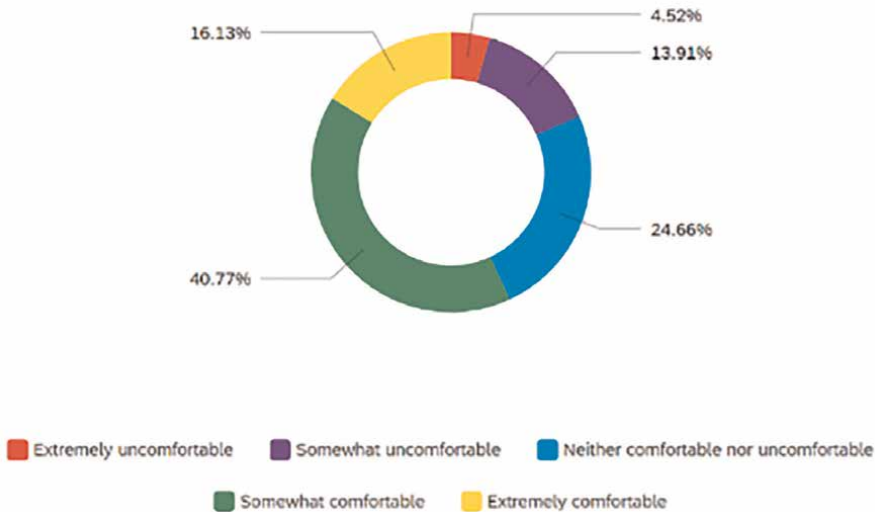


Figure 4.
Level of comfort with technology in general.

13.91% of the educators were somewhat uncomfortable, and only 4.52% of them were extremely uncomfortable. Almost one-fourth of the respondents reported being neither comfortable nor uncomfortable with technology.

At the same time, it appears that female educators are slightly more comfortable with technology than male educators, with a higher percentage of female educators reporting feeling “somewhat comfortable” or “extremely comfortable” with technology in comparison to male educators. However, the difference is not very significant, and both genders report a relatively high level of comfort with technology in general.

There is, however, a difference in grade level with an overall trend of increasing comfort with technology as the grade levels progress. The highest level of comfort

with technology is reported among the 6–8 grade level group, with 42.23% reporting being somewhat comfortable and 19.72% reporting being extremely comfortable. The Pre-K through Kindergarten group reports the lowest level of comfort, with only 15.56% reporting being extremely comfortable with technology. It is also notable that the percentage of respondents who report being extremely uncomfortable with technology decreases as grade level increases, with the highest percentage of extremely uncomfortable responses coming from the Pre-K through Kindergarten group at 8.89% and the lowest coming from the 6–8 grade level group at 2.67%.

Technological proficiency appears to generally increase with age. Educators who are 18–24 years old have the highest percentage of respondents who feel “neither comfortable nor uncomfortable” with technology, while those who are 55–64 years old have the highest percentage of respondents who feel “somewhat comfortable” or “extremely comfortable” with technology. It is also notable that the percentage of respondents who feel “extremely uncomfortable” with technology generally decreases as age increases, while the percentage of respondents who feel “somewhat comfortable” or “extremely comfortable” with technology generally increases as age increases. This suggests that younger educators may benefit from more training and support to increase their technological proficiency.

5.4 Preparation and use

Next, training and preparation prior to their role in the classroom was considered with regards to technology (**Figure 5**). When asked about the amount of training they received in technology as part of their teacher-prep program, the respondents had varying levels of experience. A moderate amount of training was the most common, reported by 35.07% of respondents. This was followed by a lot of training, which was reported by 33.01%. A great deal of training was reported by 10.96%, while 15.08% reported receiving only a little training. A small percentage of respondents, 5.87%, reported receiving no training at all on technology as part of their teacher-prep program. When considering the ages of respondents, the majority from each age category claimed to have received at least some training on technology in general during their teacher-prep program. The age category with the highest percentage of respondents who claimed to have received a lot or a great deal of training on technology in general was the 18–24-year-old age category, with a combined percentage of

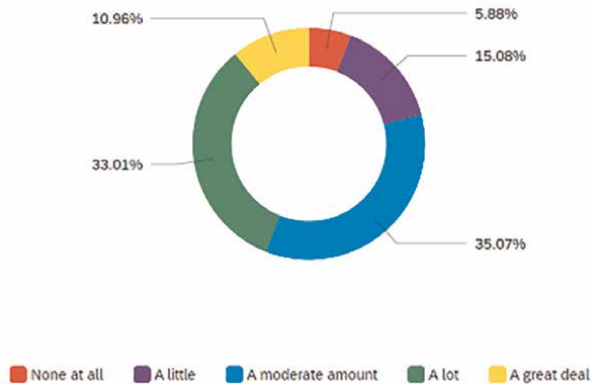


Figure 5.
Amount of training on technology received as part of teacher-prep programs.

35.91%. The age category with the lowest percentage of respondents who claimed to have received a lot or a great deal of training on technology in general was the 55–64-year-old age category, with a combined percentage of 36.8%. Therefore, while comfort with technology was reported to increase by age, training seems to have been present in more recent teacher-prep programs.

When asked how open they were to learn new technology, the majority of respondents (56.74%) answered “probably yes” or “definitely yes,” while 19.01% answered “probably not” or “definitely not.” The remaining 24.24% said they “might or might not” be open to learning new technology. Overall, the results suggest that a significant proportion of educators are open to learning new technology, but a non-negligible minority may be resistant to doing so.

Educators in the 18–24 age group tend to report feeling less comfortable with technology but are more likely to have received a lot of training in technology through their teacher-prep programs. They are also more likely to feel open to learning new technology. Educators in the 25–34 age group tend to feel more comfortable with technology than the 18–24 age group but are less likely to have received a lot of training in technology through their teacher-prep programs. However, they are the most open to learning new technology. Educators in the 35–44 age group tend to feel more comfortable with technology than the 18–24 age group and are more likely to have received a moderate or a lot of training in technology through their teacher-prep programs. They are also very open to learning new technology. Educators in the 45–54 age group tend to feel less comfortable with technology than the 35–44 age group but are more likely to have received a moderate or a lot of training in technology through their teacher-prep programs. They are also open to learning new technology. Educators in the 55–64 age group tend to feel less comfortable with technology than the 35–44 age group and are less likely to have received a moderate or a lot of training in technology through their teacher-prep programs. They are, however, the most open to learning new technology (**Figure 6**).

Overall, it is important to note that regardless of age, the majority of educators report feeling at least somewhat comfortable with technology, and the majority are open to learning new technology. However, it is also clear that there are differences in the level of technology proficiency and training across different age groups, which should be taken into consideration when providing technology support and professional development opportunities for educators. With that in mind, we sought to determine what (if any) AI tools educators had personally used from a list of popular options (**Figure 7**). Scikit Learn had the highest percentage of usage at 22.18%,

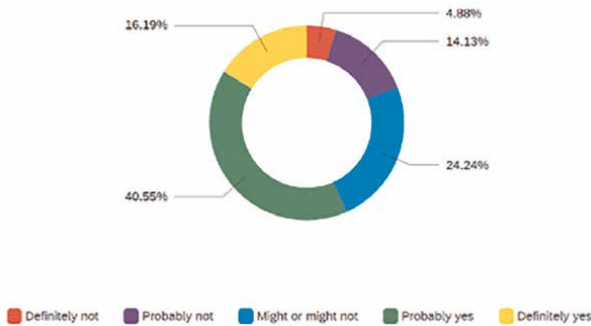


Figure 6.
Educator openness to learning new technologies.

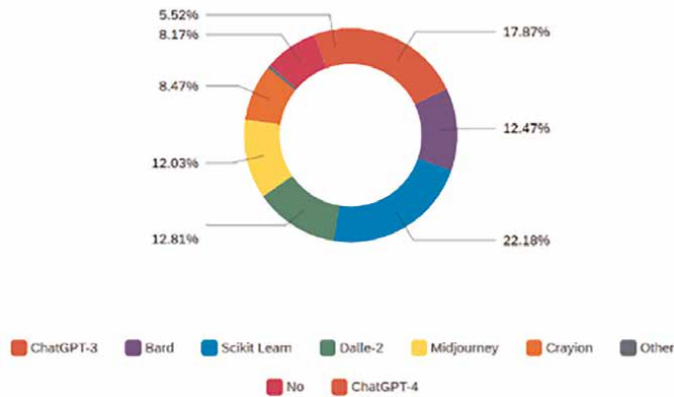


Figure 7.
Educator experience with types of AI tools.

followed by ChatGPT-3 at 17.87 and Dalle-2 at 12.81%. Bard and Midjourney were also used by a significant portion of respondents at 12.47 and 12.03%, respectively. Crayon had the lowest percentage of usage at 8.47%, with ChatGPT-4 being 17.87% and less than 3% respondents indicated that they had not used any of the listed generative AI tools. There is a negligible difference between grade levels of tool usage.

Again, broken down by age, there appears to be some differences in the generative AI tools used. Specifically, for ChatGPT-3, the youngest age group had the highest usage at 30.85%, while the oldest had the lowest usage at 15%. The same trend can be seen for the use of Bard and Scikit Learn. Overall, the data suggests that younger age groups (between 18 and 34), have a higher usage of these tools than older age groups (45–64). Considering male and female respondents, the most commonly reported AI tool used by both genders was Scikit Learn. Both genders also reported using ChatGPT-3 and Dalle-2, but male educators reported slightly higher usage of ChatGPT-3 and female educators reported slightly higher usage of Dalle-2.

In order to address upskilling, participants were asked what current access to technology and technology training were available to them. A significant portion of educators reported having average to good access to technology and technology training. 32.04% of respondents reported average access, while 33.24% reported good access. 15.31% of respondents reported excellent access to technology and technology training. However, a smaller proportion of respondents reported poor or terrible access, with 12.54% reporting poor access and 6.87% reporting terrible access. This suggests that while many educators have adequate access to technology and training, there is still room for improvement in ensuring that all educators have equitable access to these resources (**Figure 8**).

5.5 Perceptions of AI

We asked participants about their general perception of Artificial Intelligence (AI) technology (**Figure 9**). The majority of respondents had a positive view of AI technology, with 39.26% reporting somewhat positive and 19.51% reporting extremely positive perceptions. A significant minority of respondents had a negative perception of AI, with 13.10% reporting somewhat negative and 4.28% reporting extremely

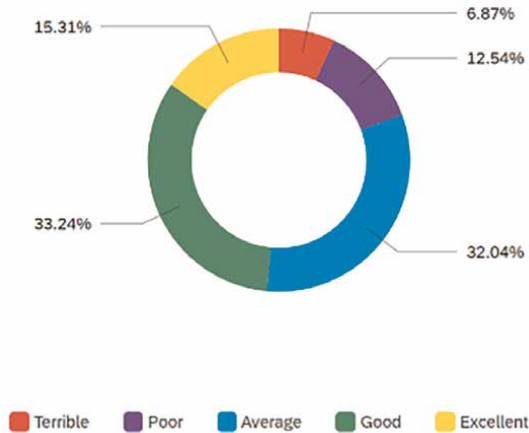


Figure 8.
Educator current access to technology and training.

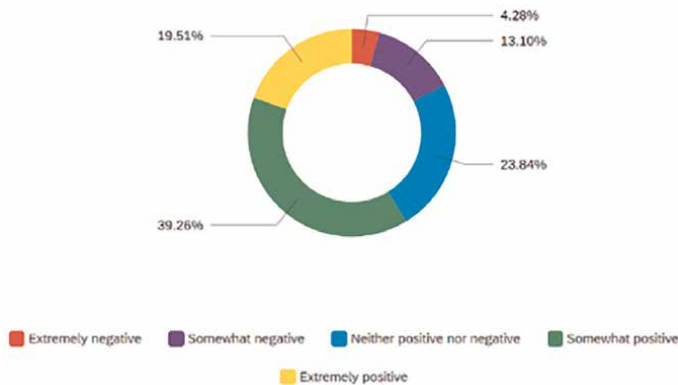


Figure 9.
Educator general perception of artificial intelligence (AI) technology.

negative perceptions. A sizeable proportion of respondents (23.84%) reported having a neutral view, neither positive nor negative, towards AI technology.

Looking at the last set of data, there are some differences in the perception of AI by age group. The youngest age group had a slightly more negative perception of AI, with 12.90% reporting an extremely negative perception and 16.13% reporting a somewhat negative perception. The oldest age group had the highest percentage of respondents reporting a neutral perception of AI, with 33.33% reporting a neither positive nor negative perception. The middle age groups all had a higher percentage of respondents reporting a somewhat positive perception of AI, ranging from 40.60% to 44.21%. It therefore seems that the perception of AI is generally positive among K-12 educators, with only a small percentage of respondents reporting an extremely or somewhat negative perception.

When asked if they had knowledge of the types of resources that would be necessary to implement AI into their classrooms, the majority of respondents (75.26%) answered “Yes” (**Figure 10**). This suggests that many educators perceive the

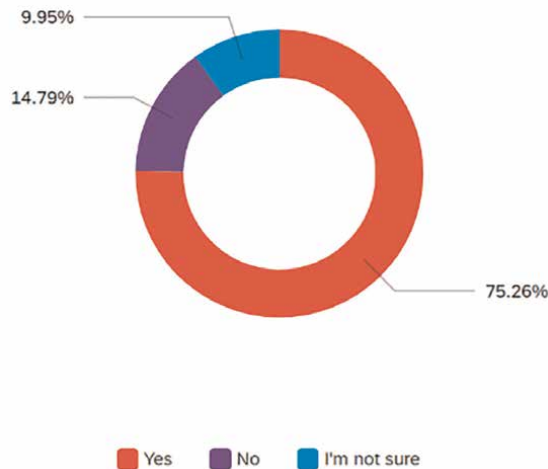


Figure 10.
Educator perception of resources required to implement artificial intelligence (AI) in classrooms.

implementation of AI in their classrooms to require a significant number of resources. On the other hand, a smaller proportion of respondents (14.79%) answered “No”, indicating that they do not believe they would need a great deal of resources to implement AI. A small percentage of respondents (9.95%) were not sure whether or not implementing AI would require a great deal of resources. These results suggest that many educators believe that implementing AI in the classroom would require a substantial investment in resources.

5.6 Infrastructure and integration

Considering the logistics of integration, the next set of questions dealt with access and infrastructure. We asked educators if the majority of their students had access to the internet at home (**Figure 11**). The results show that 67.23% of educators reported

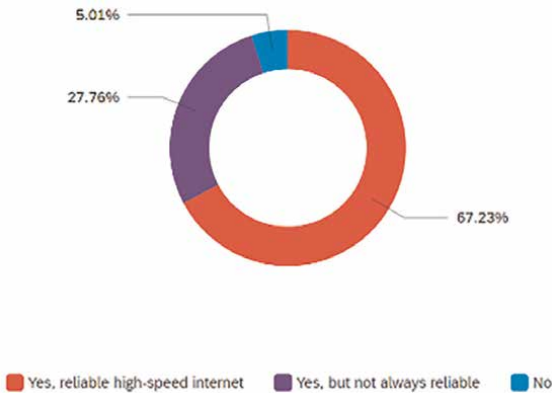


Figure 11.
Student access to reliable internet at home.

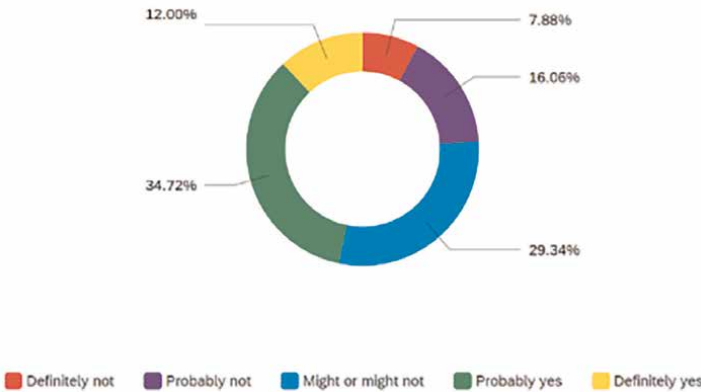


Figure 12.
Educator familiarity with free tools requiring little to no training.

that their students have reliable high-speed internet access at home. 27.76% reported that their students have access to the internet at home, but it is not always reliable. Only 5.01% reported that their students do not have access to the internet at home. These results indicate that a large majority of students have access to the internet at home, with only a small minority lacking access.

Educators reported that access to reliable high-speed internet is highest in urban districts, with 76.10% reporting that their students have such access. Suburban districts also have relatively high access, with 58.94% of educators reporting reliable high-speed internet access. Rural districts lag the other two, with only 47.49% of educators reporting reliable high-speed internet access. Rural districts have the highest percentage of educators reporting that their students do not have access to the internet at home, with 17.86% reporting no access compared to 2.49% in urban districts and 5.02% in suburban districts.

Next, teachers were asked if they were familiar with the free tools that could be used with little or no training (**Figure 12**). We asked how familiar they were with free tools that may be available to them that would allow them to utilize AI technologies with little to no training required. The majority of respondents (34.72%) said probably yes, while 29.34% of respondents said they might or might not be familiar with these tools. A smaller percentage of respondents said they were definitely not familiar (7.88%) or probably not familiar (16.06%) with these free AI tools. Only 12.00% of respondents said they were definitely familiar with these tools.

6. Recommendations

Based on the nationwide survey responses, educators generally seem to have an overall positive perception of artificial intelligence (AI) technology. The majority of educators reported being open to integrating AI into their classrooms, with many reporting that they would be willing to learn and adopt new technologies. However, the results also indicate that educators have concerns about the cost and time required to implement AI in their classrooms, as well as the availability of necessary resources, such as reliable high-speed internet and hardware. In order to address these concerns, we recommend responding to educators' needs across the field.

First, there should be targeted efforts to increase the comfort level of educators in the 45–64 age range, likely those who have been teaching for 20 or more years, with technology and AI. Training programs, workshops, and other resources should be made available specifically for educators to help them feel more comfortable and confident in using AI tools in the classroom. Additionally, younger educators could be encouraged to take on leadership roles in their schools or districts to help support older colleagues with integrating AI into their teaching.

Second, different grade levels have varying levels of access to AI tools and technology. To address this, districts should consider implementing a more equitable distribution of resources across different grade levels. For example, younger students may benefit from simpler and more accessible AI tools, while older students may require more advanced resources. Additionally, school districts should prioritize the allocation of resources to those schools in rural and remote areas where students have less access to reliable internet and other technology resources.

Third, the data suggests that there are significant differences in access to technology and AI tools, across regions, with respect to gender, and diversity. School districts should work to ensure that all students, regardless of geographic location, have access to the same resources and opportunities for AI education. This may require increased funding for technology infrastructure in certain regions, as well as partnerships with local businesses and organizations to provide additional resources and support. Gender representation must be addressed in the field of AI and technology. School districts should work to encourage girls and young women to pursue careers in technology and AI and provide mentorship and other resources to support their success. Additionally, schools should strive to create an inclusive and welcoming environment for students of all genders and backgrounds to encourage engagement and interest in AI and related fields. Therefore, to effectively address the integration of AI in education, it is important to consider the varying needs and circumstances of different age groups, grade levels, regions, and gender representations. By implementing targeted efforts to support educators, ensuring equitable access to resources, and creating an inclusive environment for all students, we can help ensure that every student has the opportunity to engage with and benefit from AI education.

6.1 Applications of AI in integrated STEM

We recommend that the barriers to effective AI integration identified in this study be addressed with an integrated approach. The hallmark of education today includes student learning experiences that are integrated, providing connections across subject areas, with real-world authentic applications to students' everyday lives. State and national standards across the STEM content areas, value student centered pedagogical approaches that allow students to engage in data collection, analysis, synthesis, and application [51].

The integrated STEM education approach values student engagement in collection and analysis of data. Teachers and students can use AI tools to collect data. For example, when engaged in a science activity, students can collect weather data—temperature, humidity, pressure, wind speed and other parameters—on their own and with AI. They can use AI to make sense of the data and the trends over time. Use of AI tools allows students to spend time applying their knowledge to solving problems. When attempting to code large data sets, AI can help students identify common

themes and trends in the data so they can spend time applying knowledge to address problem-based challenges.

Experiments can be simulated, moving teacher practice away from canned procedures and allowing students to engage in authentic experiences. AI-powered simulation software to create virtual experiments in a safe and controlled environment. AI tools can help students create and test prototypes. For example, students can use AI-powered design software to create 3D models of their ideas, which can then be tested using AI-powered simulation software. This can help students develop their creativity and innovation skills, while also giving them hands-on experience with engineering design.

A key component of STEM education is communication and collaboration. AI tools can support project work, idea sharing, brainstorming—all stages of the collaborative problem-solving process. AI can be integrated across all subject areas to enhance learning, shifting the time spent in classrooms from rote work to application of skills and ideas. These skills have the potential to better prepare students for the STEM workforce—a priority of K-12 education across the nation.

7. Conclusion

Teachers are the most crucial element in achieving effective teaching and learning through selected pedagogy, processes, and tools for enhancing instruction. This study emphasizes the need to prepare teachers for AI learning, demonstrating their openness and willingness to integrate AI into classrooms. Data analysis revealed that AI is viewed as a crucial concept for all students, regardless of their grade level. However, the results identified several gaps in AI policies, technology training, and awareness of AI tools among educators. To address these issues, recommendations are proposed, including the need to enhance technology and AI training in teacher-prep programs and provide continuous professional development opportunities for current educators. It is also essential to increase awareness of AI tools and resources through workshops, seminars, and hands-on demonstrations. The fostering of positive perceptions of AI among educators is vital, emphasizing the benefits of AI in improving teaching and learning outcomes and addressing any misconceptions or concerns that educators may have. Additionally, improving access to technology and infrastructure is essential, including the provision of reliable internet access, hardware, and software. Lastly, developing comprehensive AI policies that outline ethical and responsible practices for AI implementation in the classroom is necessary, addressing issues such as data privacy, algorithmic bias, and digital equity.

By implementing these recommendations, schools and districts can create a supportive environment for the successful integration of AI technologies in K-12 education across content areas. This will enhance teaching and learning outcomes, prepare students for a future increasingly shaped by artificial intelligence, and ensure that AI technologies are employed in a manner that benefits all students. Moving forward, it is crucial to identify resources and training programs to provide teachers with the skills to effectively incorporate AI into the classroom, while also addressing potential data privacy concerns. Adherence to district policies, state-level Individual Education Acts, and HIPAA regulations is vital to protect student privacy and ensure ethical AI usage in the classroom. Therefore, it is imperative for all stakeholders to collaboratively establish clear guidelines and best practices for data storage and management, enabling beneficial use of AI integration in education while protecting student privacy and centering the perspectives of professional educators.

Appendix. Survey instrument

You are being asked to participate in a survey conducted by Drs. Kathryn Arnone and James Hutson at Lindenwood University. We are conducting this survey to learn about your perceptions and the perceived impact AI will have on education in your district. It will take about 5 minutes to complete this survey.

Your participation is voluntary. You may choose not to participate or withdraw at any time by simply not completing the survey or closing the browser window. There are no risks from participating in this project.

WHO CAN I CONTACT WITH QUESTIONS? If you have concerns or complaints about this project, please use the following contact information: Dr. James Hutson jhutson@lindenwood.edu. If you have questions about your rights as a participant or concerns about the project and wish to talk to someone outside the research team, you can contact (Institutional Review Board) at irb@lindenwood.edu.

By clicking the link below, I confirm that I have read this form, and decided that I agree to participate in the project described above. I understand the purpose of the study, what I will be required to do, and the risks involved. I understand that I can discontinue participation at any time by closing the survey browser. My consent also indicates that I am at least 18 years of age. You can withdraw from this study at any time by simply closing the browser window. Please feel free to print a copy of this information sheet.

I currently teach

PreK
Kindergarten
First Grade
Second Grade
Third Grade
Fourth Grade
Fifth Grade
Sixth Grade
Seventh Grade
Eight Grade
Ninth Grade
Tenth Grade
Eleventh Grade
Twelfth Grade

Is your institution public or private?

Public Private
Other

What is your age?

18–24
25–34
35–44
45–54

55–64

65 or older

What is your gender identity?

Male Female

Non-binary/third gender Prefer not to say

Are you Hispanic/LatinX?

No

Yes

Please identify your race/ethnic heritage (check all that apply)

American Indian or Alaskan Native Asian

Black or African-American

Native Hawaiian or Pacific Islander

White/Caucasian

Other

Which best describes your school district?

Urban

Suburban

Rural

Which state do you teach in?

AK AZ AR CA CO CT DE DC FL GA HI ID IL IN IA KS KY LA ME MD MA MI MN
MS MO MT NE NV NH NJ NM NY NC ND OH OK OR PA PR RI SC SD TN TX UT VT
VA WA WV WI WY

Does your district have policies on the use of artificial intelligence (AI) and its use?

Yes

No

Not sure

If so, what are they?

Does your district have a policy to teach technology in an ethical and responsible way?

Yes

No

I'm not sure

In general, how comfortable are you with technology?

Extremely uncomfortable

Somewhat uncomfortable

Neither comfortable nor uncomfortable

Somewhat comfortable
Extremely comfortable

As part of your teacher-prep program, how much training did you get on technology in general?

None at all
A little
A moderate amount
A lot
A great deal

How open would you say you are with learning new technology?

Definitely not
Probably not
Might or might not
Probably yes
Definitely yes

Have you personally used any of the following generative artificial intelligence (AI) tools?

ChatGPT-3
Bard
Scikit Learn
Dalle-2
Midjourney
Crayion
Other
ChatGPT-4
No

What is your current access to technology and technology training?

Terrible
Poor
Average
Good
Excellent

What is your general perception of Artificial Intelligence (AI) technology?

Extremely negative
Somewhat negative
Neither positive nor negative
Somewhat positive
Extremely positive

Do you feel as though you would need a great deal of resources to implement AI into your classroom?

Yes

No

I'm not sure

Do the majority of your students have access to the internet at their homes?

Yes, reliable high-speed internet

Yes, but not always reliable

No

How familiar are you with free tools that may be available to you that would allow you to utilize AI technologies with little to no training required?

Definitely not

Probably not

Might or might not

Probably yes

Definitely yes

How familiar are you with free tools that may be available to you that would allow you to utilize AI technologies with little to no training required?

Conflict of interest

The authors declare no conflict of interest.

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Adoption of Educational Fourth Industrial Revolution Tools Pre and Post-COVID-19 and the Emergence of ChatGPT

Vusumuzi Maphosa and Mfowabo Maphosa

Abstract

The COVID-19 pandemic forced governments, industry, and educational institutions to deploy digital platforms to minimise disruptions in daily life. Institutions that had adopted Fourth Industrial Revolution (4IR) tools minimised learning disruptions by quickly migrating to the online environment. 4IR tools include artificial intelligence, virtual reality, robotics, intelligent tutoring and natural language processing systems. Although migrating to the online environment was challenging for most developing countries, COVID-19 offered a rare opportunity to leapfrog into a new digital trajectory. Our study considers COVID-19's effects on education and the ethical issues arising from adopting 4IR tools and pays particular attention to the impact of ChatGPT. The results show unprecedented and accelerated adoption of 4IR tools during COVID-19 in developed countries while developing countries struggled. We highlight 4IR affordances, constraints and ethical issues. Affordances include independent learning, chatbots, virtual reality and intelligent tutoring systems. Concerns include bias, academic cheating, surveillance, data privacy, and unavailability of policies. 4IR development is private-sector-led; educational institutions and governments need to formulate policies that safeguard the integrity of education. We highlight future scope and opportunities for 4IR tools in education, current limitations and future research trends. We propose a research agenda which evaluates the impact of ChatGPT on education.

Keywords: education, adaptive and interactive learning, fourth industrial revolution, natural language processing, ChatGPT, ethics, surveillance, academic cheating

1. Introduction

Ever since the outbreak of the COVID-19 pandemic, governments, industry and educational institutions have been under pressure to deploy digital platforms to minimise disruptions to daily life. The pandemic catalysed the metamorphosis of educational delivery in developing countries which had remained stagnant through

traditional teaching methods. These could no longer serve the needs of 21st-century learners. COVID-19 resulted in the global acceptance of online learning as a substitute for in-person teaching and learning. COVID-19 forced the massification of online education in Africa, which had previously faced many implementation hurdles [1].

At the onset of the pandemic, migrating to the online environment became a stumbling block as staff and students developed negative attitudes towards acceptance, citing unfamiliarity with online instruction tools [2, 3]. Countries that had not yet embraced the fourth industrial revolution (4IR) tools for education relied on social media sites like WhatsApp and pre-recorded radio programmes for teaching and learning [4, 5]. Institutions that had embraced 4IR tools, such as AI, virtual reality, e-learning, chatbots, and augmented reality, quickly migrated to online and remote learning without teaching disruptions. Due to unfamiliarity with 4IR tools, many learning institutions in developing countries failed to conduct lessons at the pandemic's peak as they shut their doors to the public. Other challenges with migrating to online teaching during COVID-19 included poor connectivity, lack of resources and difficulties students and lecturers face adapting to the new norm [6].

African scholars have expressed optimism that disruptions in traditional learning caused by COVID-19 will bring reformation and innovation to an education system that has long since lost relevance [7, 8]. Thus, the uptake of technology-mediated education will have a tremendous impact on the educational landscape in Africa. The transition will require a paradigm shift from content creation, lecture delivery and examination processes. Many countries have positively responded to COVID-19 disruptions by implementing broad strategies to enhance online learning adoption [4].

COVID-19 negatively impacted the global economy, resulting in reduced funding for education when learning institutions were at their most vulnerable state [9]. Institutions failed to get financing for ICT gadgets, upgrading their broadband infrastructure and training staff and students [10]. For learning institutions, moving to the online environment resulted in revenue loss as students no longer needed to use halls of residence and recreation facilities as they moved to their homes. Muftahu [9] reports that academics and students in developing countries perceived online teaching and learning delivery as too difficult and abrupt, with no preparation. They required prior training and more adoption time. COVID-19 also altered the lives of undergraduate students who could not experience the extraordinary life of being on campus [11]. As the pandemic subsided, institutions gradually moved to blended and in-person learning. Parents raised optimism that COVID-19 raised the momentum to migrate to online learning and would lower tuition fees signalling a significant change in education delivery. COVID-19 offered new opportunities for research on the global adoption of educational technologies as vast amounts of data were generated from these virtual environments [12].

Despite the delays in embracing digital technologies by most developing countries, the World Economic Forum (WEF) reports that over 65% of primary school learners would pursue careers and work in new occupations that currently do not exist [13]. The 4IR is changing every aspect of the global economy through technologies such as artificial intelligence (AI) and robotics, intelligent tutoring systems (ITSs), virtual reality, blockchain and neuro-technologies [14]. COVID-19 saw the optimum use of advanced learning technologies (ALTs), which support independent and self-paced learning. ALTs include ITSs, game-based education, and extended-reality systems [15].

4IR technologies played a pivotal role in service provision across all sectors during the pandemic and have continued to do so post-pandemic. In healthcare, many AI-powered applications, such as screening patients for symptoms, were used to save

lives. As movements were restricted, patients relied on virtual platforms for information access, diagnosis and medical advice [16]. In education, robots and chatbots were used, with multilingual chatbots overcoming language barriers in multinational institutions [17]. Recommender systems are used in online learning to assist learners in choosing content, career paths and qualifications [18]. Chatbots are ideal in supporting learning pre and post-COVID-19 as they facilitate interpersonal communication by responding to user questions in a natural language. Robots were also deployed at airports and public areas to detect infected people and curb the spread of the virus. In public libraries and hospitals, robots were used to disinfect books and contaminated sites [19].

Educational institutions use 4IR tools to automate administrative and repetitive tasks while deploying robots, chatbots and intelligent tutoring systems to improve teaching and learning [20]. Instructors use AI tools for repetitive and time-intensive tasks while being freed from these mundane tasks to work on higher-value tasks which require judgement [21]. AI applications can improve student recruitment and retention to increase throughput rates in specialised fields such as engineering [22].

Although 4IR tools are transformational, African countries face challenges such as limited infrastructure, cost of data and a lack of access to devices. The World Bank reports that only a quarter of the African population has access to the Internet [23]. Only a fifth (18%) of learners in Sub-Saharan Africa have access to the Internet, and a tenth to a household computer [24]. A tenth (11%) of the Sub-Saharan African countries effectively migrated into online learning, while 23% adopted broadcast radio and online learning [4]. COVID-19 stretched African universities as they attempted to migrate to online learning platforms amid challenges such as a lack of gadgets and digital skills, resistance, and high Internet costs [9]. Bryson and Andres [12] contended that learning outcomes could be undermined if the classroom learning experience was replicated online without pedagogical adjustments and the acquisition of new skills and tools. The transition to online learning during COVID-19 was abrupt, with no training for teachers and students, especially in developing countries [4, 25].

2. Concerns with 4IR tools

Although the transformative power of 4IR tools in education is undeniable, AI is adopted with anxiety and caution, considering its possible harmful effects on learners and teachers. To effectively adopt and take full advantage of AI's affordances, regulations that promote its ethical use should be developed to address constraints and stakeholder concerns. AI works on trained data; if such data has biases, it may perpetuate inequalities; thus, policies and regulatory frameworks are required to ensure that the potential of AI is harnessed ethically. Societal biases or unethical behaviour are reflected in the decisions made by AI systems since they rely on data and algorithms to make choices and decisions. Prominent issues related to the adoption of AI in education include ethics, data privacy, widening access to education, diminished integrity and suppressing its positive impact. Ghallab [26] notes that few studies focus on the inherent risks of AI development. There is a need to highlight ethical pitfalls and map a way to safeguard users of AI systems. Our chapter contributes literature on the growth of 4IR tools in education pre and post-COVID-19 and highlights emerging ethical issues and the rise of ChaptGPT. The chapter has already highlighted the impact of COVID-19 on education, the growth and the adoption of 4IR tools in education. The remaining sections highlight the following.

- The emergence of ChatGPT.
- Ethical and societal concerns resulting from the adoption of 4IR.
- Concerns with the rise and use of ChatGPT in education.

2.1 Emergence of ChatGPT

Natural language processing (NLP) algorithms such as ChatGPT are powerful tools for supporting individual and personalised learning, language translation, and interactive and adaptive learning [27]. ChatGPT stimulates positive learning experiences by providing real-time interaction and communication by providing information and instantly answering questions using a natural language. Supervised and reinforcement techniques were used to build ChatGPT, extending OpenAI's GPT-3 with a knowledge base built in 2021 [28]. Text generators such as the Generative Pre-trained Transformer-3 (GPT-3) can go through billions of sources when constructing text [29], making it appear original. ChatGPT is one of the most innovative and powerful technologies transforming education pre and post-COVID-19 as it interacts with users in human form. ChatGPT is highly intuitive and can write essays, academic papers, programming code and stories for students and the public. Some educators are thrilled by the potential of ChatGPT, while others have described its introduction as the death of essay writing [28].

ChatGPT supports self-paced learning, and those training for a skill get direct responses from the system [30]. It is ideal for students learning programming languages as they can get immediate and direct answers and, through examples, improve their skills and performance [31]. ChatGPT makes it easy to administer a multi-language class where learners may respond using their natural language. ChatGPT supports learning scaffolding, where the application can detect the student's knowledge level and adjust the difficulty of questions, allowing the student to progress in their education [27]. ChatGPT aids interactive learning by creating virtual tutors through an interactive agent that understands the learner's questions and provides appropriate responses to guide them [32]. Students can also ask questions in any subject and receive instant responses with precise feedback, thus no waiting times.

Restrictions to in-person learning during the pandemic saw examinations being taken online. There are fears that ChatGPT will compromise online evaluation as students can use ChatGPT without detection and earn higher marks. In a final MBA examination, ChatGPT produced quality responses that were better than those of students and could have earned a lower distinction (B-grade) [33]. Stock [34] laments that some text generated by ChatGPT can be attributable to the student as anti-plagiarism software still fails to detect differences between text generated by ChatGPT and human beings. Using ChatGPT will stifle creativity and critical thinking as learners increasingly depend on the chatbot. The responses from ChatGPT may not always be appropriate and accurate. As such tools enter the classroom, educators, policymakers, and governments must craft policies to guide teachers and learners to ensure responsible use. Educators need to acknowledge the affordances and constraints brought by ChatGPT and collectively work on minimising potential risks. Free accessibility of such tools cannot be guaranteed long-term once they have gained public acceptance [28]. Access to these systems is becoming subscription-based, further widening the technology divide between the Global North and the Global South.

2.2 Ethical issues

Personal identifying information is being collected at a large scale by 4IR tools pre and post-COVID-19, thus raising several ethical questions. Most public institutions do not have adequate policies to cover the increased use of digital platforms. COVID-19 has magnified our dependence on 4IR tools [35], raising security, ethical and human rights concerns arising from data breaches and undesirable outcomes.

Research shows that students have expressed anxious feelings when learning using 4IR tools when they perceive that most of their preferred careers are being made obsolete [36]. The working models produced by AI to guide learners do not explain how they arrived at particular decisions, and learners have no knowledge or skills to analyse such findings [37]. There is evidence of AI discriminating against minority groups [38], making life-threatening decisions in controversial ways, and fears of humanity being overtaken by AI [39]. To embrace AI for practical use in education, the research community must constantly assess the potential threats and vulnerabilities and develop regulatory frameworks and policies that ensure the ethical use of AI. AI-driven online learning lacks human and social aspects; learners may prefer interacting with human teachers [40]. As more learners move to AI-mediated online environments, teachers raise concerns about the lack of learning control and the failure to account for all the students. The unavailability of high-speed broadband networks in developing countries and the lack of financial resources to pay subscription fees means the knowledge and technology divide between the Global North and the Global South will widen.

2.3 Data privacy

One ethical quandary that arises with the development of AI is the large-scale collection, processing and sharing of personal information. Hongli [40] notes that varying amounts of learners' data can be easily leaked. Data leaks outside learning institutions may result in privacy violations, where personal data is used to identify individuals who may be unfairly or maliciously targeted. Students' data and educational records store highly sensitive information, and security measures must be in place to protect these records [41]. There are fears that the interests of teachers and learners are not adequately protected throughout the AI life cycle and can be easily violated. Some argue that learners must know with whom their data is being shared and be informed on how this will benefit them [42]. To ensure fairness, data subjects should be aware of the types of data collection and security methods whenever their data is collected [43]. Thus students must consent when their data is collected, know how it will be analysed and how it will assist them.

2.4 Policy

Most AI developments across the globe are private sector-led, with companies such as Pearson, IBM, McGraw-Hill, Dreambox and Coursera leading in adopting big data for personalised learning [44]. Some countries have designed policies that create synergies with educational technology companies to create innovation hubs and support the development of innovative teaching practices that contribute to evidence-based policy formulation. Most governments in developing countries struggle to enact policies to keep pace with the continuous advancements of 4IR tools for the education sector. Countries should partner with industry and academia to create AI programmes

aligned with their educational needs and improve educational systems. Thus education systems have to quickly produce workers with appropriate skills to build AI systems for the betterment of humanity. AI works in a complex ecosystem that developing countries should begin to nurture to avoid being further left behind; it includes regulation, knowledge management, innovations and business development [45].

2.5 Surveillance

AI-enabled systems are being applied in educational surveillance, raising ethical questions. The Chinese use intelligent classroom management systems to monitor learner participation and responses through facial recognition [37]. Teachers monitor student behaviour through computer dashboards to enhance instructional decision-making and scaffolding [15]. The use of dashboards for student monitoring and surveillance raises ethical questions. AI applications for curtailing academic fraud have been described as intrusive, such as using drones, webcams and keystroke detectors during examinations [46]. AI-based predictive systems have embedded surveillance techniques to predict student performance, weaknesses, strengths, learning patterns and the possibility of dropping out.

Although part of the teacher's duties involves monitoring student progress, it raises ethical questions and possibilities of cybercrimes such as bullying, stalking and exposure to sexual content when done online [47]. This threatens the learner's privacy. Students do not feel secure and confident if they know their educational activities are under surveillance from AI-based systems. In examination-based proctoring systems, students may feel uneasy by being continuously monitored, which can affect their mental health and cause them to underperform in their examinations [48]. Akgun and Greenhow [47] note that students may be apprehensive and not participate in online conversations if they know they are under surveillance. This often makes them feel unsafe and uncomfortable taking ownership of their ideas. There is great danger that educational data may find itself in the hands of law enforcement agents who may use it for surveillance.

2.6 Academic cheating

Academic cheating has long existed before, where one writes a paper for another person for a charge [49]. Still, these techniques are diminishing, as AI-based article generation is free. The rise of online learning and the commodification of education has increased cheating. ChatGPT generates assignments or essays per the teacher's guidelines and observes grammar and syntax, making it difficult to distinguish between the machine's work and the learner's. Text generators are used to produce research and thesis papers, which is academic fraud. Brown et al. [50] contended that these systems produce text that is difficult to detect that it was not written by a human being, thus promoting academic dishonesty. There are worries that ChatGPT is democratising plagiarism by offering free ghostwriting services for students and the public [34]. AI text generators instantly generate academic work for learners, opening loopholes for academic cheating [31], where the learner's competency and aptitude cannot be evaluated. Only 63% of abstracts created by ChatGPT were discovered to be fake and machine-generated; worryingly, more AI-generated text will find itself in journals and literature repositories [51]. Abd-Elal et al. [52] conducted a study to test whether current anti-plagiarism tools could detect text generated by AI; results show that text detectors failed to detect such text. It attributed this text to a human writer.

2.7 Biases from natural language processing systems

NLP systems can reinforce stereotypes and perpetuate gender biases. Such systems may associate a doctor with a “he”, a nurse with a “she”, a homemaker with a woman and a programmer with a man [26]. At the same time, ChatGPT is a powerful tool that can improve language literacy, grammar and spelling, and communication, especially for learners who are not native English speakers [27]. Users of the system must not over-rely on ChatGPT and must verify if the information is accurate and valid, as the system depends on the data it was trained on. Some biases may be related to language and culture, especially the dominance of English and Western cultures. NLP applications like ChatGPT have the potential to perpetuate some inequalities related to access to technology, especially in developing countries with limited access to infrastructure and stable financial services systems which can facilitate subscription payments.

3. Discussion

Although COVID-19 created problems for education, on the flip side, it offered undeniable opportunities for innovation and the adoption of digital tools to support a new dawn. Ratten [53] postulated that COVID-19 pushed institutions that relied on traditional forms of learning into the digital world. The global adoption of digital technologies allows everyone in the online learning technology value chain to address some emerging challenges innovatively. However, with continued disruptions to face-to-face meetings, many African learning institutions had no option but to adopt some form of technology-mediated teaching and learning. For developing countries, COVID-19 presented a once-off opportunity for learning institutions to embrace 4IR tools that support education during the crisis and transform educational delivery. This also allowed governments to assess their technology and regulatory deficiencies in supporting deploying 4IR tools for remote-based learning. These tools ensure that learning and teaching occur regardless of physical, space, distance and time limitations pre and post-COVID-19, as returning to the traditional learning model is no longer tenable. Teachers and learners will thus develop skills required for the knowledge economy as they use 4IR tools to support online learning.

The development of 4IR tools for education should be achieved through collaborative research through partnerships with learning and research institutions. Teachers and school administrators use AI-driven monitoring and surveillance systems to improve learning, but these raise ethical questions. NLP systems are redefining learning by supporting individual and personalised education, language translation, and interactive and adaptive learning, ideal during learning disruptions caused by pandemics such as COVID-19. Their use in education may perpetuate and reinforce biases against gender and minority groups.

NLP tools such as ChatGPT rely on content from algorithms that may be trained based on certain biases and stereotypes. Without policies, teachers are unlikely to detect the difference between machine-generated and human-constructed text. These systems are built using AI with the capacity to circumvent plagiarism tools. Eventually, students will develop skills to further evade plagiarism detection on material generated by ChatGPT, such as changing keywords and phrases. Although the disruptive effect of ChatGPT has come to the fore, educational institutions in developing countries are yet to consider adopting it, enact policies that support its use and address challenges such as academic dishonesty.

4. Conclusion

The COVID-19 pandemic has been transformational, forcing many institutions to reform and embrace 4IR tools to remain operational. This has led to the massive adoption of 4IR tools pre and post-pandemic as institutions try to stay operational and minimise disruptions. Although most developing countries have infrastructural challenges, the outbreak of COVID-19 forced learning institutions to adopt 4IR tools such as online learning, virtual reality and intelligent learning systems to sustain teaching and learning after in-person learning was banned. This trend has continued past the pandemic as returning to the traditional education delivery system is no longer feasible. As students migrate to the online environment due to COVID-19, parents, governments, and other stakeholders have raised optimism that it will widen access to education as tuition fees reduce and online services are relatively cheaper. AI is slowly replacing varying aspects of the teacher's job, and retraining of teachers is needed.

Adopting 4IR tools allows institutions to collect, process and store vast amounts of data for modelling AI-driven systems. The accountable and transparent use of algorithms in decision-making in the education sector should involve students. Student data must be safeguarded through policies to minimise abuse once it falls into the hands of the wrong people. The use of NLP systems is a welcome development. However, it raises concerns about academic fraud as techniques such as ChatGPT can write assignments, research papers and theses for students while adhering to grammar and syntax. Although these systems can improve learner outcomes, they are prone to abuse and require policy and regulation. As such, these systems are challenging to detect, and governments and educational institutions should speed up educational reforms and enact policies to protect the integrity of the education sector.

Most 4IR projects are private-sector initiated and led, and governments should create an environment that supports public-private partnerships for project-based collaborations to tap into the expertise of the private sector. The developed world should partner with and support developing countries in adopting 4IR tools to mitigate the effects of the COVID-19 crisis and for the progress of the education sector. Governments should accelerate the implementation of 4IR-powered technologies such as virtual and augmented reality, blockchain, and intelligent tutoring systems for the growth and future resilience of the education sector amid disruptions. The effect and impact of 4IR tools remain uncertain; therefore, more research is required to drive policy formulation and protect the teachers, learners and the public. We contribute to scholarship by raising ethical questions and initiating debates that stimulate stakeholders to interrogate these issues and find solutions. Scholars should further evaluate the impact of 4IR tools, particularly the emerging ChatGPT, which is disrupting the current state of education. The adoption of such tools by educational institutions is already raising debate, and this will assist in guiding future 4IR projects, especially in developing countries that are still lagging.

Conflict of interest

The authors declare no conflict of interest.

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Section 2

Alternative Assessments

Enhancing Language Education through Alternative Assessment Practices in Technology-Based Settings

Mohammad Hossein Arefian

Abstract

Given the challenging nature of large-scale standardized assessments due to the complexities, it is vital to obtain equitable assessment practices for enhancing English language learning and ability during instruction and course of study. Moving beyond standardized tests, we can use alternative assessment to incorporate learning, instruction, and measurement and develop a practical assessment approach for learning purposes regularly. Alternative assessment results from the mentioned research move have brought various alternatives to standardized tests for enhancing the quality of instruction and shifting scholarly attention toward learning rather than testing. Specifically, during technology-based assessment practices, the insufficiencies of existing traditional tests for different students' needs and purposes have created the must adopt a more user-friendly approach to assessment that can incorporate multiple intelligences, approach students' preferred learning styles, involve language learners' higher-level thinking skills, use more of authentic and real-world tasks and activities. Thus, this aims to illustrate the benefits, processes, and outcomes of alternative assessment practices in technology-based environments for enhancing the quality of language education.

Keywords: alternative assessment, assessment, CALL, language education, technology

1. Introduction

1.1 Alternative assessment

Numerous scholars, for several decades, have tried to explore novel approaches to assessment practices in order to solve the perceived problems in particular educational systems and realized the importance of enhancing assessment approaches, methods, and practices not only for measuring language learners' proficiency but also for fostering the quality of education in general and curriculum, instruction, and learning in particular [1, 2]. It can be noticed that the result of standardized tests, prepared to evaluate the linguistic capability of all language learners with one pre-established

test, cannot just emerge from linguistic performance and ability but other related factors, such as their cultures, educational backgrounds, personal, social, and contextual factors, and psychological and affective aspects [1, 3, 4]. To suitably correlate the English proficiency of language learners with their test performance, teachers, examiners, and test developers need to have profound knowledge and awareness of the nature of second language acquisition (how it is developed and processed over an extended period), the essence of how surface fluency can be different from the capability to use accurately for a specific purpose, the duration and extent needed to acquire fluency, accuracy, and appropriacy, the forms of linguistic devices utilized to meet the purpose, and the skills crucial for using those linguistic abilities. Hence, since reaching a high and advanced linguistic proficiency is cumbersome and time-consuming, the implementation of standardized assessment, which is mainly conducted at the end of the course of study, should be replaced with more practical and micro-assessment practices [3, 5, 6].

Given the challenging nature of large-scale standardized assessments due to the complexities, it is vital to obtain equitable assessment practices for enhancing English language learning and ability during instruction and course of study [7–9]. Moving beyond standardized tests, we can use alternative assessment to incorporate learning, instruction, and measurement and develop a practical assessment approach for learning purposes regularly. Alternative assessment results from the mentioned move of research have brought various alternatives to standardized tests for enhancing the quality of instruction and shifting scholarly attention toward learning rather than testing. The insufficiencies of existing traditional tests for different students' needs and purposes have created the need to adopt a more user-friendly approach to assessment that can incorporate multiple intelligences, approach students' preferred learning styles, involve language learners' higher-level thinking skills, use more of authentic and real-world tasks and activities [10]. Touching the heart of instructional practices, [11] pointed out that alternative assessment has received global acceptance in English language teaching, as the process and assessment of learning English are complex, and teachers and test developers need to improve the link of assessment, instruction, and learning.

Alternative assessment practices can offer numerous benefits for language learners and teachers in different ways. According to the [12], one such example can be the authentic attainment of complicated results by measuring higher-level skills, namely reflecting, creative thinking, problem-solving, and synthesizing. The alternative assessment can possess genuine, performance-oriented activities conducted in a real-life, authentic context and inform teachers of how assessment and instruction can interact to obtain a clear vision of students' abilities. It can also foster the connection between learners and teachers, teaching and assessment, objectives and outcomes, and stakeholders and parents. According to [13], alternative assessments pay attention to language learners' progress over the course duration, add adaptability in time and performance, and decrease the anxiety learners experience. Furthermore, it can provide a non-intrusive approach to everyday classroom practices, implement tasks that are linked with meaningful instructional activities, concentrate on both the process and product, become keen on various cultures, and boost clarity in the anticipated assessment standards and criteria [14, 15]. Although the term alternative assessment has been extensively mentioned in the literature, further investigations are required to comprehend the depth, process, and results alternative assessment can have, specifically in a technology-based environment.

2. New assessment approaches

2.1 Alternative assessment versus traditional assessment

Alternative assessment has been coined differently: “alternative assessment,” “direct assessment,” “informal assessment,” “authentic assessment,” “performance assessment,” and “descriptive assessment.” Despite their differences, these terms share some common fundamental characteristics [16]. So, this chapter selects the term “alternative assessment” as it is more generic and includes other characteristics. Alternative assessment practices can be a significant source of acquiring a dynamic and evolving picture of language learners’ academic and linguistic development, judging learners’ improvement in language with nonconventional strategies [17], contextualizing assessment practices in day-to-day teaching practices and learning activities [18], and recording the documents about how students processed and finished the real-world tasks with the means of L2. Hence, it is likely that, while conducting the alternative assessment, teachers focus on perceiving and recording English learners’ improvement and strengths [19, 20] and consider learners’ learning preferences and styles of learning, along with cultural and educational features.

Despite numerous advantages of alternative assessment, [21] posited that it could have various disadvantages and issues related to its time-consuming nature and subjectivity, reliability, and validity. Others believe that alternative assessment can be called additional assessment-performing in association with conventional assessment approaches to comprehensively include multiple modes of assessment. While traditional assessment used multiple-choice, true-false, and short-answer questions that were objective and selective, alternative assessment possesses an integrative and productive form that is primarily subjective and performance-based. Whereas traditional assessment focuses on single-effort, indirect, and inauthentic tests that are timed, performed individually, offer no feedback and contextualization, and are standardized and norm-referenced, alternative assessment is a criterion- and classroom-based assessment, performing a direct and authentic assessment process, that continuously engages learners in groups with projects in a context that resembles a real-world setting along with constructive feedback [22]. Shifting from traditional assessment toward alternative assessment resulted from the inadequacy of standardized tests to document students’ strengths and improvement [23, 24]. There can be more reflective and self-directed attempts during the alternative assessment, making students active agents of development and change in their particular contexts [25–27].

Numerous alternatives are in conjunction with the alternative framework, such as using qualitative designs, rather than quantitative psychometric approaches, perceiving literacy as a social and integrative practice in contrast to discrete ones, conceptualizing literacy as multiple tasks and activities, and relying on qualitative data as a substitute to quantitate one. Other previously neglected variables have become paramount in alternative frameworks, namely affective, meta-cognitive, and cognitive strategies, behaviors, collective communication, and the pursuit of personal/community aims. Moreover, the alternative process focuses on building upon criteria about the expected process of language acquisition based on research findings, collaborating and negotiating among the individuals [28], employing teaching strategies that can lead to developmental change and progress, possessing dynamic and active exploration and evaluation of teaching and learning practices, and using the results to inform instruction and further modifications in practices. The required data must

be accumulated from various sources continuously and be analyzed to help teachers, students, and stakeholders gain awareness.

2.2 Types of alternative assessment

Language teachers can adopt alternative assessment practices instead of standardized ones, such as proficiency checklists, benchmark systems, peer- and self-evaluations, observations, achievement profiles, and portfolios. The three common types of alternative assessment approaches are authentic assessment, performance assessment, and constructivist assessment [29]. Similarly, Reeves [30] recommends three major approaches to incorporating alternative assessment into online environments: cognitive assessment, portfolio assessment, and performance assessment. Thus, scholars and researchers dynamically use the term performance-based, alternative, and authentic assessments. In performance assessment, students are actively involved in producing responses that can be observable, and the tasks and activities used in a particular context are appropriate and reflect real-world context [31]. As put forward by Elliott [7], practically, English teachers can select assessment tasks and activities linked to the previously taught content, inform them beforehand of the expected established standards and criteria for directing the performance of their tasks, prepare learners with clear examples and models before conducting tasks to demonstrate standards practically, motivate learners to execute self-assessment strategies and interpret learners' linguistic abilities and performances in relation with other criteria. Some of the alternative assessment methods mentioned above are illustrated in the following paragraphs.

Portfolios are conceptualized as a "purposeful collection of student work that exhibits the student's efforts, progress, and achievements in one or more areas" and "the collection must include student participation in selecting contents, the criteria for judging merit, and evidence of student self-reflection" [32]. Students must choose the content, have a selection guideline, follow the criteria and standards, and gain reflective opportunities [33]. Accordingly, Hamp-Lyons and Condon [32] stated that portfolios, as student-centered, reflection-based, and progress-oriented tasks, must include multiple works with different ranges in a rich context with delayed assessment over a period. So, students need to invest considerable energy and take enough responsibility to take action, record performance, results, and efforts, and inform stakeholders and others to gain feedback. There are numerous benefits to portfolios, considering when assessment includes more of students' authentic tasks, is a more performance-based, student-centered, learning-oriented, and self-directed mode of learning, focuses on development over time, shares the results in a novel way, and informs parents with their learners' continuous improvement [34]. Portfolios assess multiple sources and products of learners across time to perceive growth and development, recognize how students work differently in various tasks, focus on the quality of work, and offer self-reflection and peer-reflection opportunities. Moreover, electronic portfolios are a technology-oriented type of genuine learner-centered assessment that works like the traditional one. Electronic portfolios, called e-portfolios, involve collecting carefully chosen works of thoughts, experiences, and practices in an online and computer-based setting for enhancing education, making decisions, and changing different aspects. So, during synchronous and asynchronous online classes, students can document their learning products and experiences, have self- and peer-assessment, follow their progress over time, and find their positive and negative points in language knowledge and performance. Hence, they need to process, create, and record their linguistic and non-linguistic products through videos, written

passages, and reflections to show their learning growth. Some necessities of e-portfolios can be a high internet connection, students' positive attitudes and motivation, ethical concerns, and sufficient time and budget. Furthermore, it must be systematic, inclusive, authentic, informative, personalized, and prearranged. Another common tool used as an alternative assessment is regarded as a project.

Projects is an individual or group work that encompasses authentic, real-world tasks and processes, shows students' perceptions of a particular task, needs students' previous experiences, and requires students' attempts, plans, and strategies to be completed, such as a research project, presentation, and artwork. One such regular project is problem-based learning, which demands learners' problem-solving skills in a particular context [29]. Projects can lead to problem-solving, collaborative and cooperative learning, and meaningful negotiation, vital tasks in acquiring a second language. The duration of projects can range from several days to months, depending on the purpose and commitment of the project. For conducting projects, it needs to be associated with the goals of the curriculum and course, learners' needs and interests, the novel characteristics of higher-order thinking, creative work with a sufficient level of authenticity and accuracy, and involvement and engagement by taking responsibility [35]. Given the purpose-driven nature of projects, students must have a shared aim and purpose to work toward reaching the desired outcomes, such as writing a novel, report, or article. Hence, it can be used to assess students' linguistic performance during and at the final stage of the project.

2.3 Technology-enhanced assessment

Since the arrival and spread of the Covid-19 pandemic created a shift of focus toward online education, the knowledge, ability, and tools to conduct and process electronic- and technology-based learning successfully gained paramount importance for teachers, parents, and stakeholders [36]. So, virtual teaching and learning, online educational courses, and synchronous and asynchronous online platforms have received substantial attention. While online learning is more rapid, student-centered, engaging, convenient, and approachable, it requires facilities, literacy, and training for teachers, students, and stakeholders. One recent concern in online learning is the effectiveness of online assessment practices. When teachers and others improve academic development, reliability, validity, and practicality [21, 37–39], security [40], assessment methods [41], administrative efficacy [39], and teachers' and learners' attitudes [42], they can enhance technology-based assessment practices. Various techniques and strategies are used for implementing technology-enhanced assessment in language classes. Technology is regarded as a substitute for traditional assessment practices in class and a tool for solving the perceived problems of the contexts. Several researchers consider that technology-enhanced assessment can positively influence students' achievements and engagement [37]. Similarly, Marriott and Lau [43] discovered that technology-based assessment improves students' engagement and motivation.

It is stated that the theoretical realizations are the same in classroom-based and technology-based assessment, but the teachers' roles and duties change [44]. Teachers must employ valuable strategies in technology-based assessment settings to inspire deep learning, facilitate assessment practices, and meet the needs of learners' characteristics (e.g., age, gender, and others) [45]. The learners also were noticeably satisfied with technology-based assessment practices as they enjoyed the assessment focus which was based on learning purposes and the nature of it in the technology-based environment [21, 46]. Technology provides a novel chance to use formative and summative

assessment for continuously evaluating students' learning and linguistic performance. Although using assessment and testing in online settings has been researched previously, implementing alternative assessments in technology-based assessment practices needs to be deeply investigated. Since English learners in online settings usually become passive recipients of knowledge, cheat during exams, Google their answers while responding teachers' questions during class, record the materials and content in a pdf file without thinking deeply and memorizing, and engage less in cooperative learning. So, teachers need to professionally change their instructional and assessment practices to heighten the quality of students' learning. Thus, alternative assessment methods, namely authentic assessment, performance-based assessment, projects, portfolios, self- and peer-assessment, proficiency checklists, benchmark systems, and observations, are assumed to make students active, systematic, flexible, cooperative, transformative, responsible, self-directed, and motivated in improving their linguistic capability and performance. In addition, the employment of alternative assessments in technology-based environments can offer feedback as a vital component in learning [47]. Also, the delivery, form, and strategies used for feedback in technology-based environments can be uniquely varied [48]. The implications of this study can help teachers, students, and stakeholders to pay closer attention to the contributions of alternative assessment, as a learning-oriented assessment practice, in technology-based settings.

3. Method

This study is a review paper of 15 articles (see **Table 1**) that were selected purposefully from professional journals. The keywords searched to find appropriate and relevant articles were alternative assessment, technology- and computer-based assessment, and learner-oriented assessment. The articles were all indexed in Web of Science, Scopus, SSCI, ISC, and Eric journals. The articles were read several times by the researcher to find different perspectives, benefits, and applications of alternative assessment practices in technology-based environments to enhance language

Title	Authors	Journal	doi	Keywords
Alternative Assessment for Transitional Readers	Beaumont, de Valenzuela, & Elise Trumbull	Bilingual Research Journal	http://dx.doi.org/10.1080/15235882.2002.10668710	Alternative assessment
Crisis and Changes in Learning Behaviors: Technology-Enhanced Assessment in Language Learning Contexts	Alavi, Dashtestani, & Mellati	Journal of Further and Higher Education	https://doi.org/10.1080/0309877X.2021.1985977	COVID-19 crisis; technology-enhanced assessment; e-assessment; online learning; online pedagogy; technology literacy
What Kind of Alternative? Examining Alternative Assessment	BALLIRO	Tesol Quarterly	—	Assessment; Alternative assessment

Title	Authors	Journal	doi	Keywords
Rethinking alternative assessment	McNamara	Language Testing	—	Alternative assessment; Testing; education
Alternative Assessment	Al-Mahrooqi & Denman	The TESOL Encyclopedia of English Language Teaching, First Edition	https://doi.org/10.1002/9781118784235.eelt0325	Assessment; Alternative assessment; Formative assessment
Assessment at a distance: Traditional vs. Alternative Assessments	Dikli	The Turkish Online Journal of Educational Technology	—	Traditional vs. Alternative Assessments
Learning-oriented assessment: a technology-based case study	Keppell & Carless	Assessment in Education	https://doi.org/10.1080/09695940600703944	Assessment; Learning-oriented; technology
Technology enhanced assessment in complex collaborative settings	Webb & Gibson	Education and Information Technologies	https://doi.org/10.1007/s10639-015-9413-5	Assessment; Collaboration; Assessment for learning; Assessment of learning
APPROACHES TO ALTERNATIVE ASSESSMENT	Hamayan	Annual Review of Applied Linguistics	—	Alternative assessment
An Ecological Perspective on Classroom-Based Assessment	CHONG & ISAACS	Tesol Quarterly	https://doi.org/10.1002/tesq.3201	Ecological Perspective; Classroom-Based Assessment
Demystifying Iranian EFL teachers' perceptions and practices of learning-oriented assessment (LOA): challenges and prospects in focus	Derakhshan & Ghiasvand	Language Testing in Asia	https://doi.org/10.1186/s40468-022-00204-2	Alternative assessment; English as a foreign language teacher; Formative Assessment; Learning-oriented assessment
Influence of an integrated learning diagnosis and formative assessment-based personalized web learning approach on students learning performances and perceptions.	Wongwatkit, Srisawasdi, Hwang, & Panjaburee	Interactive Learning Environments	https://doi.org/10.1080/10494820.2016.1224255	Formative assessment, web learning

Title	Authors	Journal	doi	Keywords
Perceptions of self-assessment literacy and self-directed reflection during online learning for Iranian EFL student teachers.	Arefian	Reflective Practice	https://doi.org/10.1080/14623943.2022.2096584	Reflection; online learning; self-assessment;
The alternatives in language assessment.	Brown & Hudson	TESOL Quarterly	https://doi.org/10.2307/3587999	Alternative assessment
How convincing is alternative assessment for use in higher education?	MacLellan	Assessment & Evaluation in Higher Education	https://doi.org/10.1080/0260293042000188267	Alternative assessment; higher education

Table 1.
Reviewed articles.

education. The analysis and interpretation descriptively elaborated the main themes and benefits of alternative assessment, how it can be practically conducted in real classes, and what implications this study provides.

4. Implications

Highlighting the significance of alternative assessment practices for solving educational problems and boosting the quality of education, instruction, and learning in a practical manner for learning purposes has altered the focus of educational purposes, so as to link learning, instruction, and evaluation. Hence, when language teachers involve learners with alternative assessments, students engage their different intelligence, favored learning styles, and analytic, reflective, creative, and higher-order thinking with real-world and authentic tasks and activities.

Technology-based and online learning requires more student-centered learning, teaching, and assessment approaches. Thus, assessment in online education needs to be reconsidered by language teachers. Alternative assessment practices in a technology-based learning environment can technically make assessment more genuine, performance-based, authentic, direct, and active. By using tasks, projects, and practices that students need to conduct in their daily practices within an online environment, students can become more active in making decisions, agentic in their use and learning, productive with their linguistic performance, and open to change and relearn formally and informally. Students can become familiar with the standards and criteria to reflect on their learning process, identify the gaps and strengths, change their perceptions and practices, record the result, and receive constructive feedback from others. Furthermore, students, emotionally, can decrease their anxiety, have more motivation, and become adaptable.

Different alternative assessment techniques available for teachers, such as reflective practices, projects, portfolios, observations, and checklists, can be used in technology-based settings to make assessment a constructive way to enhance the

quality of learning. Teachers can assign authentic tasks, give students options, pass some responsibilities to students, create groups and pair works, motivate and encourage them, add novelty to the tasks and exercises, give them timelines and guidelines, and prepare them with some other relevant tasks and instruction before conducting and performing. After this stage, students need to perform individually or in groups, direct their own practices, complete the tasks, focus on the quality, take decisions, ask for help, think positively, cooperate with others, and practice four skills (speaking, writing, reading, and listening). After finishing their tasks, they need to gather their work through projects, portfolios, tasks, and products to receive feedback, know their gaps, plan ahead, and work to progress.


To this end, language teachers can use alternative assessment practices to enhance the quality of language education. This study can inform teachers, stakeholders, and parents to incorporate this mode of assessment for learning purposes. Other studies can empirically observe how this approach can be applied in real classes, gather students' and teachers' perceptions, and quantitatively examine the impact on learning.

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Learning out Loud: A Framework for Learning in an Era of Information Abundance

Karen Caldwell

Abstract

Learning out loud (LOL) is an approach to learning and teaching in an era of information abundance and the changing state - and role - of formal education (K-12 and higher education, training and development programs). LOL frames a learning experience that extends beyond the traditional, centuries-old emphasis on encoding, or taking in information in formal settings, by expanding the storage, or sense-making process, stretching and sustaining retrieval, or application of content, and adding “bookends” of emphasis on motivation in the early stages and sustainability and flexible transfer toward the latter stages. In this way, a learning experience framed by LOL extends beyond the formal setting through authentic, emotional, and applied learning journeys. Based on theory and extensive empirical research from cognitive science and the science of learning, LOL addresses two pressing challenges for learners, the role and relevance of formal learning and the mismatch between how we feel we learn best and how we actually learn best. Learning out loud maps a learning journey to harness information abundance, seize the opportunities of the changing state and role of formal education, and scaffold individualized and collaborative sense-making.

Keywords: learning out loud, authentic assessment, ICAP framework, science of learning, information abundance, dual coding, drawing, generative learning

1. Introduction

Learning out loud (LOL) is a cognitive science-based framework that harnesses digital media to engage educators and learners in a structured, individual and collaborative goal-directed learning journey. I define successful learning as being able to remember, retrieve, and flexibly apply content, be it knowledge, skills, and/or attitudes (KSA). In other words, learning is made up of memory and transfer.

The process of learning “out loud” is goal-directed, starting internally with motivation and attention on “to-be-learned” content. Internally, learning *out loud* is akin to consciously pausing and pondering, or thinking. Thinking = attention = focus. Cognitive scientist Daniel Willingham’s powerful truism, “memory is the residue of thought” [1], suggests that the more you focus on and think about something, the greater the likelihood you will remember it. Through a learning out loud approach, learners then express the thought “out loud” through speaking, drawing, gesturing,

and writing. The sense-making process is both individual and collaborative – illustrating and expressing understanding in observable (audible, visible) ways with tangible outputs, or products of learning.

Outputs reflect learners’ understanding, achieved through the LOL process, and enable the learner to extend their understanding to authentic contexts and applications beyond the formal learning environment, such as online and in the workplace.

The learning out loud process, then, begins with attention and progressively involves observable behavior and tangible products that demonstrate learning – being able to remember and flexibly apply the content – followed by extension and maintenance, ideally through reciprocal interaction with others. Moving from conscious, focused, but passive intake of content through active processing and comprehension leads to inferences and construction of knowledge through connection-building with long term memory, including schema (mental models), and extends through interaction with others to co-construct and deepen understanding and therefore, learning. The passive, active, constructive, interactive continuum draws from Chi’s ICAP theory of learning [2], while the learning experiences embedded in the iterative cycle reflect strategies from the science of learning.

This chapter describes how, in formal learning environments, the LOL framework implements cognitive science, embeds universal design for learning (UDL), and harnesses digital media to facilitate learning, achieve learning goals, and solve performance challenges for diverse learners in the digital era of information abundance.

Given that approaches such as ICAP, the science of learning, and UDL exist, and infinite information and affordances from online spaces and digital media abound, why am I introducing learning out loud, yet another approach? LOL offers a port in the often chaotic storm of teaching and learning in an era of information abundance and evolving notions of formal learning. It collates and structures theory, research, and practice into a tangible, clear, and evidence-informed framework to address two pressing challenges in formal learning environments (e.g., higher education). This chapter begins by outlining the challenges and highlights the primary features of learning out loud and how it begins to address the challenges.

2. The problem: Two challenges in formal education

We face two challenges in formal education:

- its role and relevance are in flux, and
- common perceptions of how learning happens are outdated and lack empirical support.

2.1 What is the “why” of formal education?

The role and relevance of formal education is best understood through the current “epidemic of disengagement” [3] not only in K-12 and higher education, but also in the workplace. In the K-12 environment, research led by Julie Evans, CEO of U.S. education non-profit Project Tomorrow, has amplified the voices of students, parents, teachers, and school leaders since 2003. Findings prior to and during the pandemic suggest that only half of students in grades 6–12, for example, feel engaged in their learning when they are in school [4]. In higher education institutions, not only are enrollments

continuing to decline, college students are increasingly disengaged [3, 5, 6]. At the same time, employee disengagement has reached its highest level since 2015 [7].

Two silos, formal education and the workplace, face challenges attracting, recruiting, and retaining engaged students and employees. Further disconnecting the two silos is the growing trend of job seekers no longer requiring qualifications from higher education institutions (HEIs) or other formal credential-granting environments [8, 9]. Higher education, the oldest, most traditional example of formal education is a natural context to explore these challenges and ask, “What is the role of university or college learning today when increasingly, job seekers no longer require degrees?”

Higher education institutions face disruptions in their role and relevance to students, employers, and society in a post-COVID era of information abundance, expanded training and development opportunities, and the epidemic of disengagement [3, 5, 6]. One answer lies in the “reach” of HEI. As higher education scholars Levine and Van Pelt note, “In times of rapid change, higher education has done well to maintain its foothold in the library but has lost its hold on the street” [10]. HEIs, they explain, are most successful when they fulfill their role in bridging the “library” and the “street”, figuratively having one foot in “humanity’s accumulated knowledge” and another in the real world, where the pace and scale of change happens in real time [10]. HEI classrooms and their ecosystems such as student services are strategically positioned to bridge or connect the library and street through evidence-informed instructional practices and connection-building. In other words, deep, meaningful learning experiences with application to authentic contexts.

However the institution itself requires a significant shift in practice.

The shift in practice is, however, slowed by the second challenge for HEIs, outdated and misinformed notions of how learning happens.

2.2 The mismatch between feelings and evidence of learning

There is a mismatch between how we *feel* we learn best and how we *actually* learn best. The mismatch is best understood through nature and nurture. Starting with nature, we tend to resist the types of learning experiences that lead to deep learning, and instead, favor those that involve greater ease of processing. This is due, in part, to our brain’s natural instinct to conserve energy. Active engagement in the learning process, especially the cognitive effort of processing of something new, draws on precious brain energy (metabolism). Our brains take up 20% of our resting metabolism despite representing only about 2% of our body weight [11]. And learning something new is one of the most expensive, energy-intensive activities for our brains to engage in [12, 13].

We have evolved, in part, by carefully conserving energy, so *actively* learning something new can be unpleasant and uncomfortable. When cognitive effort is increased during active learning, for example actively solving novel problems in a university classroom environment, we tend to associate the energy expenditure as an indicator of less effective learning. Paradoxically, we view less active learning experiences more favourably. To illustrate, research with science students at Harvard University suggests that when learners are more passively engaged in learning with greater ease of processing, for example by listening to a skilled lecturer, they associate their comprehension and comfort levels as more *effective* [14]. This passive engagement coupled with comprehension is termed the illusion of fluency (or knowing) and it affects learners’ perception of how easy it will be to remember the information, due in large part to the ease of explanation by the instructor and ease of retrieving the information from short-term memory, for example during the same class [15]. Research findings

consistently indicate, however, that more active, effortful engagement leads to stronger memory, increased performance, and transfer of learning [14, 15].

Nature, then, presents a mismatch between how we *feel* we learn best and how we *actually* learn best. Nurture, in this case our academic or learning culture, has also contributed to the mismatch in our understanding of how we learn best.

The academic culture in HEIs across millennia have been based on transmission of scarce information. Over a thousand years ago, the holder of knowledge – typically an elite member of the community – “held” important information and was often one of the few literate members of the community. Over time, literacy rates increased, information became more readily available through the formation of universities and later, the advent of technologies such as the Gutenberg Press, radio, television, and now, the internet. Nonetheless, the dye had long been cast for formal learning, with universities such as Oxford University “masters” (lecturers) “transmitting” knowledge through lectures centuries before mass copying of books became a reality. This 1000-plus years tradition of “learning by lecture and memorization” [16] means that content knowledge is “delivered” or transmitted verbally and through textbooks. It is driven by scarcity as a core element, with knowledge and expertise representing the commodity and learning, the demand [17]. Each subject area has relatively small numbers of experts in an HEI so when “access” to experts is in person through a traditional lecture, the supply and demand model requires learners to receive content from (listen to) the knowledge holder, or “expert”.

As a result, a ‘pedagogy of scarcity’ developed, which is based around a one-to-many model to make the best use of the scarce resource (the expert). This is embodied in the lecture, which despite its detractors is still a very efficient means of conveying certain types of learning content. [17].

The pedagogy of scarcity has not been overwhelmingly disrupted by the digital era and new media, nor has a pedagogy of abundance become dominant. Disruption in higher education and beyond is afoot, however not at a large scale. Indeed, most higher education instructors, especially in large-enrolment classes, rely on traditional, one-to-many “delivery” methods [14]. In an information abundance (and access) paradigm shift, teaching and learning is primed for seismic shifts.

This new media environment can be enormously disruptive to our current teaching methods and philosophies. As we increasingly move toward an environment of instant and infinite information, it becomes less important for students to know, memorize, or recall information, and more important for them to be able to find, sort, analyze, share, discuss, critique, and create information. They need to move from being simply knowledgeable to being knowledge-able [18].

In higher education, bridging the library and the street requires instructional practices and structured learning processes that engage learners in this “border crossing” from knowledgeable to knowledge *able* [18]. Being knowledge *able* requires competencies to navigate the abundant “instant and infinite information” in both the library and the street and make meaningful connections and contributions, whether personal, community, or career related.

The good news is that cognitive science and more broadly, education research, offer myriad evidence and theory-informed strategies and approaches to guide learners (e.g., science of learning [19]) and educators (e.g., heutagogy, rhizomatic learning [20]).

However, the not-so-good news is that there remains no single, unifying framework that flexibly integrates these resources for adult learners and their educators. Learning out loud is a first step in integrating research, seizing the era of change in formal learning environments such as HEIs, and empowering learners and educators alike.

3. Learning out loud: A learning journey

Learning out loud (LOL) is an iterative, non-linear flexible learning journey. Learners can apply the approach independently, and a growing number already do in networked, participatory learning communities.

Of particular relevance to educators is the growing number of learners engaging in self-directed learning experiences independently and collaboratively, based on personal or academic interest. Research by the non-profit organization Project Tomorrow (www.tomorrow.org) and its Speak Up project draws on survey and interview data gathered since 2003 from over 6.2 million K-12 education stakeholders [21]. CEO and lead researcher Julie Evans calls this emerging form of independent, informal exploration “free agent” learning [4]. Findings suggest that, outside of formal learning environments, motivated and self-driven learners are shaking off the constraints of the scarcity pedagogy they experience in school, and actively navigating the information abundance landscape quite successfully:

The increasingly ubiquitous availability and access of digital tools and resources such as social media, mobile devices, online communities, and digital games is the fuel that is propelling this new learning paradigm of Free Agent Learning. Students' learning potential is no longer restrained by the knowledge of their teacher, the resources within their classroom, or their ability to visit a local library or museum. A world of knowledge and learning experiences can now be accessed with a few clicks or swipes on their personal smartphone. Empowered with access to technology and a passionate motivation for highly contextualized learning experiences, students are now “Free Agents” in the sense that they can drive their own educational destiny just as professional athletes with free agency have the capacity to direct their own career fate. Most importantly, the experiences that students are having outside of school, driving their own learning experiences, using a wide range of digital tools and resources, and using those experiences to prepare for their future success, are influencing their expectations for in-school learning as well [4].

These expectations in K-12 are not new, and HEI educators like Michael Wesch [18] are at the forefront in seizing the “new media environment” (p. 69) in formal, “in-school” learning to scaffold learners’ journey from being knowledgeable to knowledge *able*. A learning out loud framework facilitates this journey. To introduce the key features of learning out loud, I address the educator primarily, rather than the independent learner. Below, the descriptions and examples relate to asynchronous online learning environments, however the activities and principles apply to all modalities.

In many ways, learning out loud reflects the iterative processes of free agent learning, beginning with personalized motivation for learning and culminating in collaborative engagement via learning networks that can (and should) occur beyond the classroom. **Table 1** provides an overview of the learning out loud stages and forms of cognitive engagement. More detailed explanations follow, with concrete examples, and finally, more in depth explanation of the two main cognitive science theories and approaches that inform LOL and provide extensive empirical support (**Table 1**).

Learning out loud stage	Engagement
1. Motivation, purpose and focus (curiosity, interest)	attention
2. Exploration of to-be-learned content (reading, listening, watching)	passive
3. Comprehension and retention (memory building)	active
4. Consolidation through connection- and meaning-making	constructive
5. Extension through collaboration and co-construction	interactive

Table 1.
Stages and forms of cognitive engagement of learning out loud.

3.1 LOL stage 1: Attention through motivation

Much like the “passionate motivation” of the K-12 free agent learner phenomenon identified by Evans ([4], p. xix), adult learner motivation involves both cognitive and affective processes and can account for 30 to 40% of learning and application [22]. For this reason, learning out loud begins with motivation via explicit orientation to the topic, the to-be-learned content and prompts to pique personal connections (curiosity, interest). Orientation is not only to motivating the learner and capturing their attention, or focus, but also to establish the big picture, or overview of the topic. Schema (mental models) of concepts and their relationships are ideal to orient the learner. Our brains seek meaning before detail [23] so an emphasis on the essential, motivating and, in terms of schema, features of the to-be-learned content, by default, minimizes and eliminates extraneous content that may negatively affect cognitive load [24]. Orienting learners to no more than three to five focus areas of the to-be-learned content also supports management of cognitive load and sets them up for success, namely optimal sense-making processes [24].

To illustrate this phase, I share an example of learning and authentic assessment.

LOL-based orientation:

- provides a learner-centred overview of the topic or schema of the central concepts,
- prompts the learner to make connections to their own lived experiences, learning goals, or future applications,
- introduces the learning material (e.g., online article, podcast, video, research paper, etc.),
- foregrounds the learning activities to follow, and
- explicitly directs the learner to focus their attention on specific content (limited to 3 to 5 elements).

The last component of an LOL orientation is essential. Guiding the learner orient their attention to key concepts (and often, specific passages or excerpts) enables them to maintain focus and sets them up to achieve the learning goals with sufficient working memory, as explained by cognitive load theory [24].

An authentic assessment related to motivation begins with purpose. For example, a multi-phase e-portfolio development project begins with learners articulating their

purpose and creating a communication strategy (illustrated in an example below). The e-portfolio project is process- and product-based and learning activities are woven into the assessment when learners draft digital artifacts such as blogs and infographics as a response (personal, academic, or career-related connection) to the topic. Thus, part of the orientation stage motivates learners by linking to the e-portfolio project and its authentic application (e.g., job-seeking, lifelong learning).

3.2 LOL stages 2 and 3: Passive and active exploratory learning ... with focus

In the next two phases, learners explore the content either independently or through social annotation using digital tools such as Hypothesis, Kami or Perusall [25–27]. Learners apply the focus areas provided during the attention-building stage to read, listen to, or view the learning materials for general comprehension. Concept and comprehension checks are valuable scaffolds for this foundation-building stage.

3.3 LOL stage 4: Constructive engagement to consolidate understanding

The greatest gains in learning and performance take place between the active and constructive modes of the ICAP continuum [28, 29]. This transition happens in stage 4 of learning out loud, once learners have explored the content with the focus areas in mind and established comprehension. Constructive engagement moves learners beyond what is provided in the materials to construct meaning and identify or extend connections, either with prior knowledge, personal relevance, or simply inferences gleaned from deeper exploration. Prompts to identify and explain emerging connections, or patterns, are particularly effective for consolidating understanding as well as meaning making. For example, learners may be prompted to compare and contrast elements of the to-be-learned content, or to extract cause and effect relationships.

Learning activities at this stage typically culminate in learners explaining, giving evidence for, and illustrating their consolidated understanding through digital artifacts of their own choosing, including narrative text, word-diagrams (e.g., table, Venn diagram), screen casts, or other means. Providing learners with options to express their newly constructed, emerging knowledge enables them to go beyond the original resource (learning material) and bridge the content to an authentic purpose such as in their draft e-portfolio. Equally important is the iterative process of communicating their understanding in its emerging, unfinished “draft” form and remaining curious and open to refinement and extension of their understanding through interactions at the next stage.

Scaffolds and structure at this stage are essential to facilitating a “progress over perfection” emphasis and acknowledgement of the messiness and uncertainty of the learning process itself. As an example, scaffolds might include sample digital artifacts in draft form, grading mechanisms that reward risk, and a “guide on the side” instructional role, offering support only where needed.

3.4 LOL stage 5: Extending learning with others

The final and most effective stage of learning out loud engages the learners in meaningful, reciprocal learning interactions with others both within the learning environment (e.g., classroom) and beyond. Well-designed and scaffolded learning at this stage connects learners in collaborative work that builds on their consolidated knowledge through problem solving and other applications of the to-be-learned content.

An example is learners' collaborative design and development of training materials to teach others about the content. Each learner brings their own understanding and previously drafted products (e.g., blog with flow chart and screen cast) to the collaboration and together, the team identifies an authentic audience that would benefit from or a context in which the content is applicable. They then design and develop training experiences for the agreed upon audience and context, drawing on each of their knowledge and materials.

Again, the product(s) they co-create will be ideal artifacts to include in each individual's e-portfolio, the authentic assessment. Further, sharing their work more widely, for example via social networking environments such as Twitter and LinkedIn bridges learners more directly from the library (more structured and controlled classroom) to the street (unpredictable, socially driven personal networks).

4. Learning out loud: Two students' learning journeys

Examples from two fictitious but representative students will illustrate the LOL approach and set the stage for a discussion of the theoretical and empirical support for learning out loud.

Kayla and Salman are students in the same online asynchronous graduate class, Adult Learning and Development, a 15-week semester-long course. Kayla is a grade 6 teacher and Salman, a future physical therapist. As part of both learning and assessment, Kayla and Salman are independently designing and developing their own digital, interactive e-portfolio to synthesize their learning and showcase their competencies. Early in the course, they submit e-portfolio plans, the first assignment, in which they articulate their purpose for the e-portfolio (e.g., job-seeking, lifelong learning, professional development) as well as their communication strategy by answering six questions from Hobbs' [16] Create to Learn:

1. Who am I?
2. Who is the target audience?
3. How will they encounter this message?
4. What do I want them to know?
5. What do I want them to feel?
6. What do I want them to do?

Kayla and Salman's purposes and communication strategy responses are summarized below in **Table 2**.

Together, the purpose and communication strategy will shape Kayla and Salman's learning activities in the learning out loud processes throughout the course. In other words, the students will make choices in the learning process that align with their purpose for creating the e-portfolio, as well as their strategy for the design, development, and use (including sharing) of the end product, of the e-portfolio typically a website or e-booklet. With each week's learning activities in the online course, learners have options for how to engage with the content including curating meaningful

	Kayla	Salman
Purpose	(1) job seeking; (2) professional development (PD)	(1) lifelong learning; (2) working with physical therapy (PT) clients, potentially
Who am I (Identity)	(1) educator; (2) emerging teacher trainer	(1) curious lifelong learner, (2) emerging physical therapist
Target audience	(1) potential employers; (2) colleagues	(1) self, possibly PT clients
Encounter message	(1) LinkedIn profile, hyperlinked in resume, cover letters, and email signature block; (2) incorporated in PD sessions	(1) private site; (2) potentially in future through training form, email signature block
Know	(1), (2) that I am knowledgeable about how humans learn and develop, and am a credible, competent communicator who can use digital media effectively	(1) that there are evidence-based frameworks about how humans learn and develop; (2) that I am trained not only in PT but also in adult learning
Feel	(1) impressed with my knowledge and competencies; (2) confident in my PD design and delivery	(1) informed; (2) trusting in my training, guidance, and overall support
Do	(1) hire me! (2) learn with me!	(1) refresh my memory and apply the content; (2) follow my training guidance

Table 2.
E-portfolio purpose and communication strategies, Kayla and Salman.

content, drafting and refining digital artifacts, and applying course concepts to solve problems such as a common workplace challenge (e.g., case study or scenario).

Kayla, for example, often chooses the learning activity option to draft and refine blog posts that incorporate infographics she's created on her own or with others. Kayla makes direct, concrete connections in her blog posts to her professional context, teaching in the K-12 sector and makes evidence informed points with her target audience in mind (potential employers and colleagues). She has the option to select course concepts, such as transformative learning, to explore in relation to teacher professional development and to illustrate key concepts of transformative learning through word-diagrams. These steps align with her communication strategy for her audience to feel confident in her design and delivery of professional development.

At the beginning of the course, Salman opted to be more private with his e-portfolio, serving his lifelong learning purpose. By designing and developing a website for his curated content (e-portfolio), Salman is able to provide limited access to his instructor and peers in the class, but keep the site itself private. The flexibility of the website builder, Google Sites, enables Salman to keep the door open to adapt and use his materials, based on course content (adult learning) in his future profession, physical therapy. Salman is new to the field of education and has a healthy skepticism of its theories and approaches, so his communication strategy is to emphasize the extensive research base underpinning the content he's exploring in class. In this way, his choices each week in the learning activities tend to lean toward generalizations and broad applications. As the course progresses, he is noticing more and more connections to future applications such as working with PT clients so his iterative revisions and collaborations in the class with educators like Kayla enable him to go deeper with

certain topics. To illustrate, Salman opted to create an infographic of a research paper from the course and share it with the authors via social media. This learning process occurred over a six week period and the product itself took on multiple versions until Salman felt it was ready for an authentic audience, and also to be included in his e-portfolio.

As part of their weekly learning experiences, both Kayla and Salman re-ignite their motivation by being prompted to think about their purposes for learning in stage 1 of LOL. Each learner has quite unique prior knowledge and the “focus” prompts enable them to direct their attention to the important content. Stages 2 through 5 are not easy as neither learner was accustomed to this level of autonomy and applied engagement with the course content and each other. Nonetheless, by the end of the 15-week course, both learners become accustomed to the novel approach in which they share incomplete “drafts” of their understanding, demonstrating vulnerability and risk-taking, and along the way develop confidence in their iteratively deepening knowledge and competencies as well as their abilities to explain and illustrate their “take” on course content with credibility and through multiple modalities.

By the end of the course, each student have constructed and co-constructed both understanding and products of learning that were unique to their identities and purpose for learning. These connections are not easy to form in any learning context, nor is it to engage in effortful expenditure of precious brain energy or exploit the abundance of information and its delivery through digital media. These features of learning out loud bridge both unique learners between the library (course content) and the street (personal purpose for learning).

Features of learning out loud are less traditional but not new. They are based on extensive theoretical and empirical support.

5. Theoretical and research basis: learning plus out loud

Learning Out Loud brings together two established cognitive science frameworks, Chi’s ICAP theory of learning [2, 29, 30] and the science of learning [19]. The LOL approach is comprised of two concepts, *learning* and *out loud*, and the term is inspired by John Stepper’s social learning application to the work world, working out loud [31, 32]. After defining the two concepts, I go into greater depth in connecting them to ICAP theory of learning and two powerful science of learning approaches, Fiorella and Mayer’s generative learning [33, 34] and dual coding.

Recall my earlier cognitive science-based definition of learning as memory plus transfer. To *learn* is to construct memories, often in the form of schema schema and to be able to flexibly transfer, or apply, both. Learning experiences that happen *out loud* lead to deeper, lasting learning. Out loud learning is conscious and requires focused attention, and LOL involves alternating between expressing both emerging and established ideas and understanding *out loud* internally and externally, (i.e., in visible or audible modalities).

As a framework for learning, LOL emphasizes observable behavior and artifacts, indexing not only what learners *do* but also products they *create*. The LOL process is informed by Chi’s ICAP theory of learning and is therefore iterative, moving from passive intake of content to interactive co-construction of understanding and schema-building. Similarly, LOL incorporates generative learning and dual coding strategies from the science of learning to zoom in on learners’ specific engagement activities.

5.1 Chi's ICAP theory of learning

The ICAP theory of learning outlines four modes of physical and cognitive engagement in descending order, interactive, constructive, active, passive [28]. Physical engagement as part of learning is observable, for example note-taking, pointing, underlining, etc. Cognitive engagement is invisible and reflects thinking processes while learning. To define the four modes of engagement, both types are indexed.

Table 3 outlines key learner behaviors and products (artifacts) in each mode of the ICAP continuum.

The learning out loud approach adds to ICAP with its intentional and transparent emphasis on motivation for learning, i.e., by orienting learners toward their purpose, sparking curiosity, etc. Strategies focused on motivation and learning seem to result in similar levels of effect (30 to 40%) on both efficacy and transfer (application), which suggests a strong rationale for emphasizing motivation in learning design.

The four levels of learning with the ICAP continuum are, not surprisingly, greatest at the interactive level and least at the passive level. That is, learners engaged in interactive (co-generative and reciprocal) activities experience more and deeper learning outcomes than in constructive modes, which are more effective than active and passive. In other words, the hypothesis of ICAP theory predicts the ordering Passive < Active < Constructive < Interactive [2, 28, 29]. Learning out loud adheres to this order and adds value with specific learning strategies at each level. ICAP cannot make accurate predictions for activities within the same mode however research

Mode	Passive	Active	Constructive	Interactive
Learner behavior	paying attention, focusing (e.g., reading, listening, watching)	physically manipulating learning materials (e.g., underlining, pausing and rewinding, copying)	physically generating novel ideas or inferences observable (e.g., comparing, reflecting, drawing)	collaboration with others via reciprocal, co-generative behavior (e.g., discussion, critique,
Learner artifacts	no physical output	output already existed	output new in relation to learning materials	output new (goes beyond) learning materials and each individual's contribution
Cognitive process(es)	attention, focus, on to-be-learned content	re-focus, re-activate relevant information	produce new knowledge, infer new connections, revise existing knowledge	combine understanding and knowledge to co-construct and collaboratively new understandings
Learner and/or Instructor roles and example behavior	Establish motivation, pique curiosity, avoid cognitive overload by limiting number of elements	Annotate and interact via social annotation, share takeaways and connections, answer concept and comprehension questions	Identify connections, infer relationships (e.g., with earlier content, prior knowledge), describe patterns and/or models (schema)	Mutual contributions, reciprocal knowledge building and application of content

Table 3.
ICAP theory of learning modes.

findings suggest that the “sweet spot” where the greatest improvement in learning happens is between active and constructive modes [28]. In HEI classrooms, this space offers numerous opportunities for application of generative learning strategies, based on the science of learning.

5.2 Generative learning and dual coding

Generative learning engages the learner through the ICAP steps and is particularly relevant in building and strengthening the connective tissue between active and constructive levels. Progressing from passive to interactive co-construction modes of learning is a messy, iterative process. It is also difficult for learners and involves a series of learning experiences that spend precious brain energy while selectively and purposefully exploiting the abundance of information. Dual coding is a generative learning strategy based on the science of learning that incorporates observable behaviors and results in tangible products of learning.

Dual coding is a form of self-explaining (elaboration) that harnesses visual and verbal (words) content to convey understanding. Examples of dual coding products are word-diagrams such as notes taken with both words and imagery (e.g., sketch notes), graphic organizers, Venn diagrams, tables, flow charts, maps, cartoon strips, timelines, and infographics.

As both an instructional and learning strategy, dual coding aligns with principles of universal design for learning (UDL), namely ensuring that alternative forms of verbal (words), auditory, and visual information are incorporated in both representation (displaying content) and action and expression (communication) [35].

Dual coding as part of learning out loud can engage learners in externalizing their emerging thoughts through drawing. Drawing as an encoding technique is particularly efficacious as it uses multiple constituent processes to make and convey meaning by exploiting tools such as external memory fields. When we externalize our understanding through symbols (images, words),

we have an external memory field, in the form of an immediate display of selected artifacts, that often serves as our real working memory. The thinker holds the displayed item in the external field, and plays with that item in iterative loops, improving or extending the memory representation in the external memory field [36].

Elaborative	Motoric	Pictorial
<ul style="list-style-type: none">• Generative (constructive) processes to imagine and envision representations that capture visual and semantic features of the target concept• Deep levels of processing of (imagining, enacting) and visual imagery• Concept becomes more concrete (less abstract)	<ul style="list-style-type: none">• Manual translation of image (external or internal) from the mind to the page (external memory field)• Similar memory-enhancement as enactment effect with motor action in response to a word• Motor actions in response to words enhances retention	<ul style="list-style-type: none">• Visual processing and analysis for inspection purposes (quality, accuracy, etc.) [37]• Picture-superiority effect through two routes, visual and verbal (an image’s “label”) [38]• Dual coding of pictorial information strengthens encoding through accessing the “semantic store” [38]

Table 4.
Dual coding components and features.

Dual coding, then, builds strong multimodal memory traces, and supports working memory and comprehension, incorporating elaborative, motoric, and pictorial processes. **Table 4** summarizes key learning behaviors and effects of dual coding (from [37, 39] unless otherwise indicated).

6. Final thoughts: a novel, evidence-based solution to today's learning challenges

Learning out loud starts with learners and their goals at the centre. With evidence-based practice and authentic application of learning, LOL bridges learners (and educators) and to-be-learned content iteratively between the “library” and “the street”. The library mindset that learners develop empowers them to filter the abundance of information through step-by-step meaning-making that emerges from a “pause and ponder” internal memory-initiating process along a continuum of comprehension, connection-building with prior knowledge and experience, construction and illustration of understanding, and ideally, collaborative, reciprocal meaning-making. Connections to real-world contexts and applications also emerge, to add relevance – bridge-building – related to learners’ goals. Consistent LOL experiences have the potential to build self-directed learning out loud habits of thinking and learning. The role and relevance of formal education, then, is to bridge learners from motivation to flexible transfer of learning in real life settings.

Notably, by teasing out the notion of “active” learning which many learners’ brains resist due to its energy expenditure, learning out loud scaffolds learning into step-by-step sense-making experiences. Designing learning experiences not only with learner motivation in mind but also learners’ cognitive load capacity lays the foundation for cognitive energy expenditure that is both meaningful to the learner and manageable for their working memory and the “storage” stage of traditional learning.

From an instructional perspective, LOL begins with learner motivation, incorporates student choice, universal design for learning (multiple means of engagement, representation, and action and expression) [35], and authentic assessment. From a learner’s perspective, LOL provides a coherent and energy-efficient structure and manages expectations for the non-linear, occasionally challenging pursuit of learning. With a foundation of theory and evidence from cognitive science drawing from Chi’s ICAP Theory of Learning and, among others, instructional and learning strategies from the science of learning, (for example, generative learning and dual coding) learning out loud represents a flexible learner-centred approach.

Learning out loud frames both the learning process, or journey, and tangible actions to learn deeply and achieve performance goals. In higher education classrooms and for independent adult learners, the structure of ICAP provides a heuristic for designing learning journeys, while strategies from the science of learning provide concrete, evidence-based guidance for action.

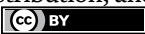
In this early, nascent stage, emerging research findings of the learning out loud approach and related features suggest promising opportunities for bridging the formal education library with the street and empower learners of all ages to harness the abundance of information in and out of the classroom and to become truly knowledge *able*.

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Chapter 6

Online Assessments in a Changing Education Landscape

Lebelo Serutla, Alfred Mwanza and Turgay Celik

Abstract

COVID-19 threatened to bring education system to its knees across the globe, forcing educators to adopt e-learning as an alternative. While other teaching and learning activities could still go ahead online, the challenge was how would authentic assessments be conducted? E-learning can facilitate administration of online assessments, allowing educators to evaluate students, provide feedback while at the same time providing students with access to assessments from anywhere and at any time. In the post-pandemic era, creativity is likely to become a critical component of online assessments, allowing the use of technology-enabled multimedia tools to enhance assessment experience to enable students various ways to demonstrate their understanding of concepts. This chapter examines role of e-learning, creativity, and technologies in online assessments and their potential to enhance educators' experience. It discusses challenges and proctoring tools used in, and also online assessments as a future permanent feature of education to support Massive Open Online Courses (MOOCs) and hybrid systems.

Keywords: online assessment, e-learning, proctoring tools, post pandemic, artificial intelligence, massive open online courses

1. Introduction

The face of higher education has changed since Covid-19 befell the globe. Hassan et al. [1] contend that learning has experienced a shift since Covid-19 global pandemic and that it will never be what it used to be as everything is changing. The benefits of the usage of information technologies through different forms of eLearning are evident, irrespective of the type of educational organization where it is provided: from universities and schools to small training organizations [2]. The current situation requires a lot of innovation and intervention [1], as evidenced by the widespread of availability and installation of Learning Management Systems (LMS) or various software applications tailored to satisfy particular requirements of learners and educators. In spite of the innovations alluded to advances in flexible e-learning systems, on the fore is the issue of online assessment which has always been a gnawing issue for educators but was amplified by the Covid-19 pandemic. Covid-19 almost brought the education system across the globe to an abrupt stop, albeit temporarily. While other learning activities, such as materials delivery, lecturing, etc. could still go on, the gap existed in the administration of authentic and credible assessments that can

be trusted. Kurniati et al. [3] asserts that online assessment is the biggest challenge to the learning process. This is true when considering that hybrid or blended learning is one of strategies for higher education in the current post-covid landscape. E-learning also supports Massive Open Online Courses (MOOCs) that enable multiple students to enroll in courses and programmes without requiring their presence on campuses. Absence of credible and authentic assessments brought about trust issues in qualifications bestowed. The traditional invigilation processes to authenticate the assessments could not be implemented, since students were locked down and scattered at various places, hence the emergence of credibility and trust issues. Holden et al. [4] allude to e-dishonesty and e-cheating as new concepts to be considered as new challenges.

E-learning can be defined as the virtual delivery of education, facilitated by mediums that enable virtual delivery of education, such as cloud, multimedia, and communication technologies [5]. These technologies have enabled 'live' remote assembly thus making it possible for lectures to be held in real-time mode [5]. These technologies have replaced traditional snail mail and its faster cousin, the e-mail. Furthermore, they have enabled an increased number of students to join classes as distance is no longer an obstacle to taking courses from any part of the world. Scattering of students over a large geographical area pose a challenge as to how they will be assessed. Though such differentiated means of teaching and learning exist, it may be difficult to converge the students together for purposes of taking assessments, thus necessitating consideration of online assessments [6]. Though this way of accessing course materials online allows unprecedented levels of flexibility and accessibility for students from around the world and overcomes geographical barriers that might prevent students accessing on-campus course offerings, it also has its own challenges especially as regard e-assessments [7–9]. Therefore in the context of e-learning and its associated activities such as assessments, requires careful planning and maximization of available online technologies to cater for a variety of individual differences, student timetables and external commitments, and assessment modes (e.g. [10–12]). Considering all such activities alluded to above, assessment as an activity, has higher stakes and therefore calls for new innovations, creativity, and a paradigm shift.

Assessment of student learning is a fundamental function of Higher Education (HE) and is a central feature of teaching and the curriculum [13]. It is also complex, multi-faceted, and influenced to a large extent by the context in which it takes place [14]. Online assessments (i.e. e-assessments) can be defined as the administration of authentic and trusted virtual assessments to a large number of students scattered over a large geographical area [15]. Assessment is a complex topic since it involves two distinct aspects. First, it forms an essential element of the learning process [16]. Second, it is the means by which academic staff form judgments as to what extent students have achieved the intended learning outcomes of a programme, or of an element of a programme [16]. Since it would be expensive to deploy invigilators to monitor the process at each of the places where there is a student taking an assessment, it leaves an assessment in danger of being compromised thus bringing its credibility, authenticity and trust into question. In addition, assessing students' practical abilities, and technical competencies, in online learning continues to be a challenge for both students and teachers [3]. Many efforts and techniques have been undertaken to quell assessments being compromised and maintain credibility and authenticity. Some of these efforts and techniques do not use technologies but rather rely on creativity and innovation while others employ technologies such as automated proctoring tools [17]. Pre-technology techniques required an extensive creativity and innovation on the part of the lecturer so as to minimize chances of compromising online assessments

while maintaining their credibility and authenticity. Online assessments should be such that they reduce chances of students neither collaborating to attempt questions nor searching the internet for answers or clues to solutions. Though there are no many empirical studies comparing integrity breaches between traditional and e-assessments, it still remains that the sudden shift to e-assessments for summative assessment calls for more research.

In the post-pandemic era, e-learning and technology are likely to play an even more significant role in education. According to a report by Technavio, the global e-learning market is expected to grow at a CAGR of over 14% from 2020 to 2024 [18]. The report attributes this growth to the increasing demand for personalized and adaptive learning solutions, the need for cost-effective education, and the growing adoption of mobile learning. The COVID-19 pandemic has presented an opportunity for educators to reimagine the role of e-learning, creativity, and technology in the post-pandemic era. E-learning and technology can enhance the learning experience by providing access to a vast array of resources, promoting collaboration and communication, and enabling personalized learning. Creativity is also crucial in education, fostering innovation, critical thinking, and problem-solving skills. Technology can provide students with tools to express themselves creatively, promoting creativity and communication skills. In the post-pandemic era, education must evolve to meet the needs of a rapidly changing world, and e-learning, creativity, and technology are likely to play a significant role in this transformation. For the benefit of students, faculty, employers, the market place (business, industry etc.), the role of online assessments cannot be overemphasized in this post pandemic arena.

The chapter is structured as follows. First, it will discuss the role of e-learning, creativity and technology in online assessments; then it will present techniques used in online assessment; then continue to cover technologies used in an attempt to authenticate online assessments. The chapter will finally culminate in discussing the future of online assessments in the face of changing education landscape where online and hybrid systems are the order of the day, by highlighting the challenges of online assessments and conclude by looking at the future of assessment and support for MOOCs and hybrid systems that stand to benefit greatly.

2. Role of e-learning, creativity and technologies in online assessment

Baneres et al. [19] states that one of the great contributions of technology in education is the evolution of assessments into e-assessments. The diverse spectrum of formative and summative assessment activities includes online quiz, online presentations, e-portfolio and assessment activities such as online essay and computer-marked online examinations respectively [20]. The role of e-learning and its associated technology can now facilitate the entire assessment process starting with the creation of assignments, monitoring of progress, marking, communication of results to as far as conducting statistical analysis. In this regard learning analytics have become a huge body of research facilitating high end analytics and dashboards. This is so because of the large footprint of data that e-learning leaves behind, enabling creativity that has led to understanding a student academic journey more formally. It is common feature now to see a large collection of learning management systems such as Moodle, blackboard, canvas, Google Classroom and MOOCs like Coursera and EdX etc., which have extensions that provide seamless interfaces to other student support systems including assessments. In the past, most LMS were used for formative assessments

and rarely for summative assessments. Yet during covid and now in the post-covid landscape, a lot of creativity has been seen in the shift to third-party software interfaced with the LMS to facilitate summative assessment for example final examinations. This has underscored effectiveness of online exams for diagnostic, formative, and summative assessments and provide students with the opportunity of demonstrating performance [16].

Applying technology in education is seen as an integral component of a teaching-learning environment that addresses the need of 21st century learners. Wanner and Palmer [21] notes that such students have different learning styles, but they are mostly internet-savvy and uses technology to help them build their knowledge. These technology-driven delivery, interaction and assessment methods such as flipped classroom, blended learning, MOOCs, and distance learning are deemed the best ways to meet the needs of the 21st century learner [21]. Since students assume more active roles in the modern methods of learning and teaching, it promotes more creativity on the part of the various stakeholders such as education institutions, technology developers and the society. Simamora [22] notes that in this arena a student become more responsible for their learning process and develop creativity and independence as a result of the distinct learning style experience each gets as a result of technology differentiation targeted at individual learning styles. The new online paradigm of learning is undergirded by several learning theories such as the theory of social learning and constructivism, where students are the active actors in their learning (Young and Jeong, 2020 as cited in [23]). Other theories include:

2.1 Net-aware theories of learning

The Net-Aware theories draw from net-based technologies which provide avenues for collaborative, informal and lifelong learning [24]. Emerging technologies driven by ICT encourage epistemic engagement in teaching-learning processes characterized by an abundance of educational information and content, enabling the learners to be active agents that compile and present relevant information according to their needs [24, 25]. The internet provides the capacity for powerful communication of multimedia content in abundance at a low cost and delivers learning information with a variety of display and presentation features, from YouTube videos to large-scale distribution and development of Open Educational Resources (OER) [26]. These tools can therefore be intertwined with e-assessment enabling self-assessment and peer assessment.

2.2 Heutagogy

Heutagogy. Heutagogy method is not only driven by advances in ICT but is centered on self-directed education and avoids the instructor dependency connected with both teaching and learning studies, which when practiced in e-learning is suitable for the 21st century and in line with the education 4.0 concept broadly accepted among the millennials [27, 28]. The millennials are technology dependent and connected via social media, making them savvy on online platforms [29]. Heutagogy provides a learner-centered environment that enables learners to design personalized learning contracts, define their own learning path, design their own assessments in a collaborative learning environment [28]. As a result, heutagogy emphasizes self-direction and concentrates on the growth of competence in the use of online tools and information, opening up new ways of advancing e-assessments. Heutagogical practices could

serve as a potent instructional method for self-diagnostic, self-formative, and self-summative assessments [27, 28].

2.3 Connectivism

Connectivism aims to grow and build learning networks through making new connections, regardless of official education systems. According to Siemens [30], knowledge and learning are today defined by connections; “know where” and “know who” are more important today than “know what” and “know how.” [31]. Connectivism learning is controlled by the network metaphor, with connections consisting of learning materials, and machines to store and generate information. Learners develop and use learning environments with the help of computers, peers, and experts in the learning network to access, process, analyze, propose, and apply information [31]. Though there are opponents of connectivism as a theory, it is evident that it is a lens through which interactions between learners, institutions and learning content is enabled through digital tools, thereby enabling both self-assessment and peer-assessments with ease as a result of this connectivism.

2.4 Groups nets and sets theory

Groups Nets and Sets Theory defines learning in terms of groups, nets, and sets with groups being seen as safe spaces where students gather (in person or online) to complete a sequence of autonomous and/or collaborative learning activities [31]. On the other hand, nets are networked learning activities, which extend connectivity beyond the learning management system (LMS) and sets are formed when people share the same interest or trait [31]. To generate a community of inquiry, well-organized groups develop significant social, cognitive, and teaching presence. These characteristics of groups, nets and sets can be extremely useful in the classroom, and in the presentation of group assessment tasks, to support both formative and summative e-assessments enabled by digital technologies [32].

Some of the online assessment tools driven by technology are Myopenmath [33], webassign, Examity, MeritTrac, ProctorU, ExamOnline, SpeedExam [34]. **Table 1** shows a list of assessment instruments, their descriptions and example online assessment tools. **Table 1** has been derived from [35]. The table outlines some of the assessment tools and the technologies best appropriate those instruments.

There has been a sustained innovations in proprietary and open-source tools to support e-learning as well as e-assessments [36]. However, the thrust has been towards e-assessment technologies that offer proctored environments.

3. Techniques to do online assessments

Principles and factors that promote and facilitate best and successful assessment practices are widely discussed in the literature (e.g., [37–40]). While the principles and factors discussed may vary, they all aim at promoting the widespread use of learning outcomes assessment in higher education, thereby elucidating the three dimensions of assessments namely evidence, interpretation and use. Online assessments need a different regime of strategies to facilitate credible assessments. Challenges of deploying invigilators due to students not being in one place further put a strain in implementing successful and credible assessments.

Assessment instrument	Description	Assessment tool
Online quizzes	Quiz questions can take a number of forms, such as multiple-choice, fill-in-the-blanks, and hotspots. One benefit of quizzes is that they are short and easy to assess	Gimkit, TriviaMaker, Quizizz, Proprofs Quizlet, Syrveymonkey,. Most LMS like Blackboard, Moodle, EdApp
Essay questions	This type of question encourages critical thinking and is best suited for evaluating higher-level learning	Moodle, Esperion, Qorrect, TAO, TCExam
Drag-and-drop activities	show a learner's ability to link information and apply knowledge to solve a practical problem. Learners are able to apply knowledge in a real-life situation.	Most LMS
Online interviews	During brief online interviews, students can demonstrate their proficiency in various areas	Google Meet, Microsoft Teams, Zoom
Dialog simulations	Help train learners for real-life conversations with customers, colleagues and others	Virtual labs, Microsoft Teams, Zoom
Online polls	They allow you to capture feedback directly from your audience on their learning experience	Monkey survey, online Forms
Game-type activities	These are considered fun and not tests, so they are good general indicator of skills and knowledge	Quizlet, Kahoot
Peer evaluation and review	Give each participant a chance to reflect on their knowledge and then communicate their feedback in a consistent and structured way	Monkey survey, online Forms
Forum posts	Use them when you want learners to interact as part of the learning process, while checking their comprehension of a topic	Blackboard, Canvas, Moodle

Table 1.
Assessment instruments and tools.

One of the challenges faced by Online assessment is that students are alone wherever they are taking the assessments, opportunities for dishonesty by gaining external help are abound. This was true especially during the covid-19 pandemic but can be generalized for situations involving MOCCs. Students can consult the internet to attempt to get answers. They can refer to physical materials such as books for help. They can consult others who might know better than them. They can even go to the extent of impersonation whereby they get other people to sit for assessments on their behalf [41]. But the issue can also be turned on its head with some authors questioning if the cameras used to observe the student while taking an assessment is not invasion of privacy. It is being questioned whether the requirement that a student shows 360degrees view of the room where he would be taking an examination is not compromising his privacy. While the intentions of showing the room to prove that the student is alone and no material that could be used to compromise the assessment are available, but that act can go beyond to show private spaces that the student may not prefer to share with the outside world [42].

Different set of strategies can be applied for different assessment environments. For instance, questions can be randomized so that one group of students get one set of question at one time and the other group, another set of questions. The situation is

then reversed after some time. Randomizing questions will ensure that even if there is a chance for collaboration, students will probably talk about different questions, thus reducing chances of dishonesty. Technique to randomize questions is possible when an assessment is taking place at scheduled time, and everybody is present and connected to the proctoring environment. Only resource rich institutions that are capable of providing live proctoring system can enable such an environment. Other techniques include blocking the web browsers to make it impossible to access the internet, the use of artificial intelligence to confirm and authenticate the student. AI can further be employed to detect intruders, using cameras and microphone, that could come from the outside to offer help and even detecting impersonation by continuously scanning the face of the students in order to affirm that it is still the authorized one taking the assessment [41, 43].

One of the biggest challenges facing online assessments exist in resource poor environments where attempts to carry online assessments are done in the absence of supervision or automatic monitoring tools. In those situations, creativity and innovation are required. Khan and Jawaid [44] lists some of the techniques used to carry out online assessments such as assignment portfolios, multiple choice questions and open book examinations. Owusu-Oware and Tanye [45] further asserts that cheating can be minimized in open book examinations if they are taken in real time. The challenge is how to minimize cheating when the examination is not taken in real time. Other studies, e.g. [46, 47] have found that students who took unproctored assessment took a long time to complete it and obtained high marks. This suggested that they had time to engage and cooperate which is a misconduct that lead to dishonesty. Lack of proctoring tools is a characteristic of resource poor institutions that have to do or carry on online assessments with limited resources that discounts any form of proctoring but could only rely on Learning Management Systems (LMS), such as Moodle and Blackboard. Owusu-Oware and Tanye [45] assert that LMS have become core platforms for providing online teaching and learning. They further assert that challenges that come with these platforms include creating assessments that accurately evaluate students' learning and are cheat proof. Cheating compromises efficacy and integrity of online assessment due to bountiful opportunities for students to cooperate or seek outside help when they take the assessment remotely without any invigilation [45].

Commercial proctoring systems have surfaced. While proctoring system proposed to solve many challenges faced by online assessment, they however, further require cutting edge infrastructure setup, software, and hardware on both the instructor and student sides [48]. There are also additional equipment such as cameras which may further burden the set up. The extra burden may disadvantage students from resource poor institutions and backgrounds. The disadvantages are further exacerbated by limited connectivity necessary for real time monitoring of assessments as students may not have enough data to enable or sustain extended periods of connectivity. In other studies, teachers experienced problems such as poor internet connection, limited internet capacity and student not having access to smartphones [49, 50]. Thus, assessment techniques employed in the absence of proctoring tools must reduce chances of online assessments being compromised in order to retain their credibility, authenticity and trustworthiness amid those constraints. This section discusses three such techniques; and those are the timing techniques, structuring of questions and use of online presentations or interviews. The thesis is that these techniques are practical and can work in a resource poor environment. They are not time consuming to implement.

3.1 Timing techniques

Use of timing technique is designed to put students under pressure so that their time to access the internet or consult with their peers is severely limited such that they would be concerned with finishing the assessment and submitting before time allocated expires. Guangul et al. [48] also suggests that setting time limits for remote assessment would discourage students from cooperating and thus limit seeking outside help to complete the assessment, as they race against time to complete and submit. Timing assessments is achieved by allocating time long enough to do the assessment and submit. The use of technologies such as the Moodle Learning management system could play an important part because the system shuts when time expires, necessitating race against time for students to complete and submit assessments before it closes when time expires.

Timing is a complex technique because students work at different speeds. Some are fast or could find an assessment manageable such that they finish quickly thus having time to share with their fellow peers who are slower. The other complexity is structuring a question to fit the time that has been allocated. The issue of designing an assessment that will take time allocated to be worked through, is a delicate balancing act as the assessment need not take too long/hard to complete (within allocated time) or too short/easy to finish quickly. The assessment must also fit uniformly across the class. This means that the question must not be too easy for a bright student and not too difficult for a struggling student so that the assessment can be completed in allocated time.

Designing such assessments is not a straightforward exercise. It requires skill, knowledge and experience of the assessor [51]. Such assessments need careful thought and consideration, for them to work. Despite giving the assessments such thought and consideration, it is not uncommon to find a number of submissions bearing glaring similarities such that it is difficult to tell them apart. Such similarities suggest that given a slightest chance, students will still find a way of collaborating and/or sharing their work with each other, thus compromising credibility, authenticity and trustworthiness of the online assessment. Sometimes footprints of compromises are left in the works. For example, one student forgot to remove the details of a student from whom she or he got the work. Sometimes evidence suggests that students get someone, more knowledgeable and experiences, to do the assessment for them. Signs of a student obtaining such assistance shows in the use of advanced concepts that are sometimes not even covered in the course. For example, some students in an introductory programming class used pointers, some used functions, some used object-oriented programming when they were being introduced to procedural programming. At this stage, students are still in their novice state, they would not therefore be expected to use such advanced concepts. The use of advanced concepts suggests that someone more knowledgeable than the student, did the work on behalf of the student.

3.2 Question structuring

The other technique is careful structuring of online assessment questions. This technique can be used with the technique of timing, as described above. Educators resorted to composing questions whose answers could not be found on the internet or reference books. Noorbehbahani et al. [52] talks about developing questions that are not prone to cheating. Even if small and scattered clues that could be found, say on the internet, it would still take a lot of time to put the answer together. With physical

assessments, access to the internet is controlled as invigilators are present when students undertake their assessments or browsers are locked to limit access to the internet. Students are also denied use of electronic devices that can be used to connect to the internet. This is not the case when students are being assessed remotely and are not at the one venue. It is therefore difficult to control students wherever they are. Therefore one of the ways used to reduce chances of copying is to reduce chances of finding answers on the internet by structuring the questions in such a way that their solutions cannot be found on the internet. The exercise needs careful consideration by examiners and it invokes their creativity in order to come up with such assessments. The exercise is a game changer, as educators have to think out of the box, contrary to what they are used to. This technique is useful in what is traditionally known as take home or open book assessments. When given a take home assessment, which is what the assessments technically became when Covid-19 stuck, allows students to browse the internet looking for answers [48]. To this end, [48] suggests that conceptual assessments whose answers cannot be found on the internet or other sources. This is done to make browsing the internet or scouting other sources for answers a futile exercise. Boettcher and Conrad [53] asserts that open book assessments in online education eliminates many problems as they can happen without need for remote proctoring. It can be observed therefore that careful structuring of questions can enable credible, authentic and trustworthy online assessment, which is suitable for resource poor environments.

3.3 Online presentations/interviews

Online presentation or interviews is a strategy that can be used to cross check or verify the student's work. It is a useful technique to counteract academic dishonesty, especially in resource poor environments where automatic proctoring tools are not available. An online presentation can be scheduled after submission and detection of dishonesty to confirm if indeed the student did the work or not. For instance, in a programming assessment, an online presentation can be arranged when a student in an introductory programming course is found to have used advanced concepts that are yet to be covered to cross check the work. The use of advanced concepts suggests that the student sought outside help. Guangul et al. [48] also found that combination of online presentations when used together with the submitted report affords the teacher opportunity to ascertain whether the student did the work or not, thereby minimizing or discouraging dishonesty.

(Li and Lalani, 2020) cited in [54] asserts that learning occurs by engaging in critical thinking, original writing, and demonstrating knowledge and abilities through academic work. With the emergence of new AI technologies, like ChatGPT, it is suspected that during online assessments, students may gravitate towards using such technologies and thus stop engaging in critical thinking and original writing required for academic work. There also is danger that large numbers of students that enroll in MOOCs will overwhelm instructors to the extent that they may not be able to distinguish between students' work and those generated by advanced AI driven technologies like ChatGPT for students who may have access to it [54]. Therefore, in those circumstances, the use of online interviews become indispensable.

Although online presentations or interviews seem attractive, they are not without challenges. Scheduling interview for a large class can be a tedious exercise, bordering on impractical. It may also be challenging to find co-assessors to sit through the extended periods when the interviews are being held. Other challenges are that

students can share interview questions with those that are yet to be interviewed leading them to gain unfair advantage. This is possible because the students would not be in a controlled environment where cooperating opportunities are bountiful.

4. Technologies applied in online assessments

As already indicated, online assessments were the missing link for entire higher education to go fully online. Already lectures, notes, discussions were happening online with great potential. Students were able to join programme remotely as the need for physical presence in campuses were reduced. Thus, e-learning enabled education in flexible manner separate from traditional norms. What was left was to plug in an online assessment in order to complete the chain. While administering assessments online is no problem, the challenge comes when question of credibility arises. Without some form of monitoring, it would be difficult to ascertain if the assessment administered in that manner is free from dishonesty. The issue arises because students will have an urge to cheat given a chance. The problem is compounded when they are alone with nobody looking over their shoulders to check if their behavior is honest. Hence the need for some form of remote proctoring. As the challenge of presenting authentic and credible assessments became glaringly apparent, entrepreneurs entered the space with tools to assist and fill the gap exposed by the pandemic. As a result, AI based proctoring system are on the rise [55] in an attempt to fill in the gap.

Absence of such tools presented an entrepreneurial opportunity for industrial giants to tap into the market of providing online assessment tools. The prevailing Covid-19 pandemic gave emergence to a myriad of tools, of varying capabilities, that can be used to help authenticate online assessments. Arnò et al. [56] discusses some of the commercial online proctoring systems that have entered the space of higher education. From their categorization, it is evident that almost all proctoring systems are for the resource rich institutions. Their poor counterparts will struggle to access those tools hence affect their students. The access factor could comprise and hence bring doubts about the quality of education provided.

There are, however, advantages brought about by proctoring systems. Alruwais et al. [57] discussed advantages to students, teachers, and the institution. For the student, benefits include instant feedback which could improve learning on the part of the student; ability to access assessment remotely, thus giving flexibility that normal pen and paper assessments do not have. Alruwais et al. [57] also states further that teachers can grade assessments and give feedback quicker than when they use traditional methods of pen and paper. On the other hand, institutions benefit by results being released quickly thus making it easy for enrollment plans to be implemented. The enrolment can also be increased as physical demand put on the institution by pen and paper assessments are averted [57].

Accommodating working and remote students can be one of the most important advantages of online assessments [42]. Costs of accessing higher education will be reduced as a consequence of not having to be physically present at an institution far away from the student [58]. It therefore improves access to higher education. Also, the advantage promotes MOOCs programmes. Also, if a resource poor student can access online assessments without need to upgrade or acquire additional equipment will be appealing and inclusive of students from all walks of life. It reduces stress of having to secure top-of-the-range equipment or acquire additional one in order to continue with studies.

All authors [55, 56, 59] agree on categorization of online proctoring systems into three broad but non-mutually exclusive groups, namely:

1. **Live Proctoring Programs.** These are the systems that require an invigilator to be present in a remote location to monitor and control activities of the students. The activities that are controlled include authentication of students. Activities that could lead to dishonesty are also monitored. If a student is judged to have violated the examination rules, the remote invigilator or proctor can interrupt the assessment process. Arnò et al. [56] reports that since introduction, live proctoring has expanded on a large scale due to increased growth of assessments. The growth can be attributed to increase in MOOCs. Also the scale of use would be increased with the set of Covid-19 pandemic, as institutions across the globe sought new ways of administering assessments remotely. Live proctoring system will likely be used by resource rich institutions as opposed to poor ones. Advantage of these kind of systems is that the assessment occurs at once for everyone involved. The drawback is that it requires resources to make it happen, on the part of the institution in the provision of human resources and equipment needed. On the other hand, students must be able to acquire necessary equipment and be able to access requisite infrastructure such as internet connectivity in order to partake in the assessment process. Live proctoring systems mimic traditional invigilation process done remotely with the help of ICT.
2. **Recorded Proctoring Systems** record the behavior of the student during assessment. It does not involve remote human proctor to control the process. A video captures all activities and log them in a database. Authorized reviewers check the recorded videos and analysis of logs for red flags that could compromise the assessment. Reviewers include teachers, professors, or other people who are charged with proctoring duties. Red flags that could be identified could lead to an assessment being disqualified for dishonesty. Recorded proctoring systems are automatic and they work independent of human interference. They have a potential to allow students to choose when and where to take an assessment. Reviewing the recordings can however add a considerable overhead on the side of the reviewers especially when the number of students who have taken the assessment is large [55]. They are also resource intensive as they require equipment that will enable the online assessment setting to be recorded.
3. **Automated Proctoring systems** use AI extensively. They are notably advanced systems that are almost fully automatic. These systems record the entire online assessment setting and later produce report detailing the authenticity of the online assessment by analyzing video, activity logs and sound recorded. In this setup, reviewers are presented with report instead of producing reports themselves. They can then agree or disagree with the analysis, in case there are signs of dishonesty. But students are given freedom to write anywhere and anytime. The systems in this category are also resource intensive especially if extra equipment to record audio-visual content is required [55].

In summary, from this broad categories of proctoring tools discount the poor rural and remote student who has intermittent internet connectivity and lacks resources to acquire equipment that is required by proctoring systems, as their cost could be prohibitive. The ability to access online assessment tools has the potential to affect

progress in further and higher education for such a student. The limitation also has potential to affect participation in MOOCs by resource poor students. Access to online assessment tools remains a challenge and it will be explored in the next section.

5. Challenges of online assessment

Bhagat et al. [60] reported that online learning integrated with social network connectivity is providing students and educators with an ecosystem of interaction and troves of learning resources. This is in part because online learning allows students the convenience and flexibility to better fit their studies in with their work and other obligations and, as [61] show, many of those enrolled in online courses are of typical college age, i.e., 18–24. While online proctoring may provide a solution to the question of exam integrity, the negative effects of such an intrusive type of monitoring on students and exam performance are not yet well known. Rohadi [49] quotes the four principles that define success of student in the 21st century. These four principles are 1) that mode of instruction should be student-centred; 2) education should be collaborative; 3) learning should be contextual; 4) schools should be socially integrated. The question to be answered, therefore, is how can these are to be realized in the phase of changing landscape of education, where online assessments are the order of the day.

There are very few studies in the realm of online proctoring specifically relating to the nexus of test anxiety and exam performance. The few studies we came across do not deal with online proctoring (i.e., webcam monitored examinations—especially those using live proctors). Baneres et al. [19, 62] states that one of the great contributions of technology in education is the evolution of assessments into e-assessments. Online assessment or e-assessment includes a broad range of assessment activities such as online essay and computer-marked online examinations [63]. Guardia, Crisp and Alsina (2017) as cited in [19] defined them as the use of information and communications technology in facilitating the entire assessment process starting with the creation of assignments up to checking to as far as conducting statistical analysis. Its effectiveness is stressed by [64] claiming that online exams are effective for diagnostic, formative, and summative assessments and provide students with the opportunity of demonstrating performance. Terpstra et al. [42] asserts that students experience high levels of anxiety during online proctoring.

The issue of access to resources is key in accessing online assessments. Although [65] assert that challenges in online assessment proctoring technologies lie in deeply rooted in problems such as educational approaches that are teacher-centred and make teachers transmitters of knowledge. They further claim that adoption of online exam proctoring technologies have produced “negative impacts on student subjectivities, pedagogical relationships and educational outcomes”. Therefore, the focus on student cheating as an “individual and interpersonal problem neglects the more fundamental issue of social and educational inequality” is utterly flawed. The social and educational inequality are not generally the problem of the rich north and the poor south but specifically of South Africa which has been labeled as an unequal society. The inequality is posing a problem to access to higher education in terms of affording fees especially for the marginalized blacks [66]. Moses et al. [67] further indicates that despite improvement in educational attainment, poor black schools still lack behind their rich white counterparts in South Africa. This inequality permeates into higher education. Challenges of access to resources is probably a third world phenomenon.

Umare et al. [68] reports that in India, the infrastructure that facilitates online teaching/learning is inadequate. Umare et al. [68] further extrapolates this to the rural parts of the developing countries, where there are issues of unreliable electric power supply; erratic network connectivity and lack accessibility to smartphones/laptops by the poor. The challenges are further compounded by little to no support from the family due to economic background brought about by constraint education.

Raman et al. [69] further indicates that it is students from remote areas who have greatest challenge of accessing the internet. According to Moses et al. [67] poverty is still rampant in rural areas, which are former homelands where blacks were forcibly moved to during the apartheid era in South Africa. Since blacks constitute majority of people, it also means that majority of students are black. And it is this majority of students who find it difficult to access the internet. Their state of poverty also means they have difficulty in accessing devices such as computers, tablets, smartphone and even cameras that are required by online proctoring systems [69]. Therefore, the requirements imposed by online assessments, namely, electronic gadgets (such as the computer/laptop, smartphone/tablet, fiber for internet connectivity and/or data) all make it almost impossible for a poor student to access online assessments proctoring, especially when the student is enrolled in a MOCCs program. It is lack of financial resources to their access to the Internet, educational materials, and equipment necessary for online learning brought by differences in social standing among the students and unequal distribution of ICT infrastructure that pose a challenge in accessing online assessments [70, 71].

E-learning requires expertise and skills in ICT. Undoubtedly, the role of experts is indispensable in e-learning but specifically in online course assessment. However, teachers and students are the frontier participants and users of these courses and their feedback, therefore, deserves more attention. Sarfo and Yidana [72] studied the involvement of lecturers in the design and development of Moodle-based courses. Their results revealed that major challenges were “low technology competencies, cumbersome institutional culture, and lack of adequate ICT facilities” [72]. Valdez and Mader [73] asserts that more effort must be exerted in, among others, training teachers in the use of ICT and designing online materials that incorporates online assessments. **Figure 1** highlights some of these issues. They also argue that in order to achieve its full potentials to promote the development of the 21st-century competencies, there are myriad challenges that will need to be addressed [72, 74].

Babić and Bubaš [51] conducted a pilot study to determine competencies of teachers to do online teaching. They established that there is a relationship among the following factors: 1) ICT and EDUTECH knowledge, skills, competencies, attitudes and skills; 2) personal characteristics of the teachers; 3) institutional factors – institutional culture; 4) situational factors. The study suggests that the question of competency is not a single-dimensional factor but a multifaceted one. The well-being of the teacher, situation that the teachers find themselves in that are largely affected by institutional factors all contribute to aptitude of teachers in acquiring skills necessary to survive a hybrid learning system, as illustrated in **Figure 1**. Therefore knowledge, skills and competencies are not standalone issues but are affected by other issues. So skills needed for success of online assessments need to be supported by policies that improve well-being of staff involved. The diagram below had been adapted from ref. [51] to show the relationships.

There are considerable pedagogical challenges that need to be overcome in order to undertake online assessments. van Rooij and Zirkle [75] lists pedagogic factors, such as collaboration, interactivity and learner feedback, as one of success factors

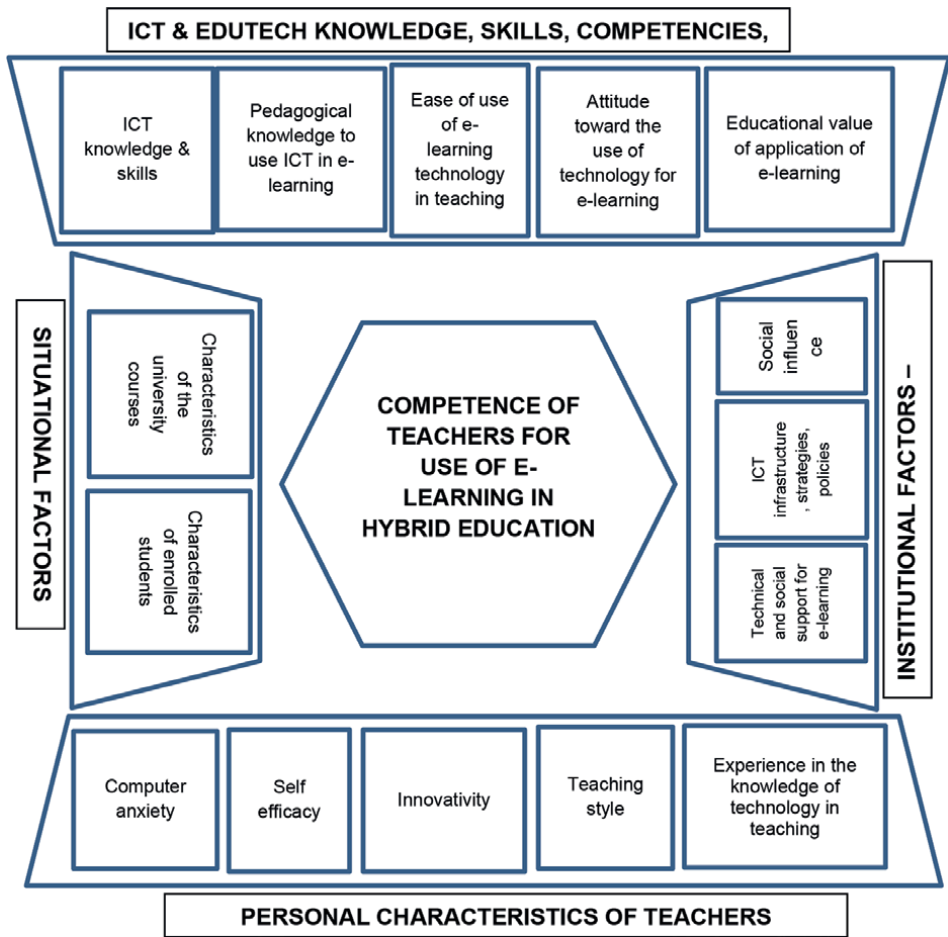


Figure 1.
Relationship between skills and wellbeing (adapted from ref. [51]).

for online learning. Institutions need to provide resources to support professional development of lectures so that they gain skills to conduct online assessments. When shifting from face to face to online assessment, lecturers need to be aware of time management, teaching styles and content development and delivery [76]. Students also need to be trained so that they are able to engage and embrace e-learning and hence online assessment. Student training will mitigate environmental challenges that students face so that they are able to cope [71]. There is also a need to provide technical support to ensure that e-learning systems, including proctoring system work properly [55, 76].

We also note that contents of online courses have far exceeded those of traditional courses, involving a line of education elements and activities, which means that there is a challenge to ensuring that all assessment objectives are clear and are met [77]. This challenge arises from the fact that there could be confusing assessment indicators systems, as well as overemphasis on experts focusing more on technology rather than subject matter [77]. van Rooij and Zirkle [75] further suggests human factors such as technology competency and motivation, a critical success factor in e-learning and hence online assessment.

Recent studies highlighted that students did not understand the necessity for online assessments due to technological incompetence of students and teachers, mistrust in the technology infrastructure and significant reliance on multiple-choice questions format. The students preferred online assessments that provide constructive, timely and personalized feedback, as well as a gradual transition towards online assessments together with technical training for both students and faculty. They also required active individualized interaction with instructors to incorporate online assessments into higher education effectively [77].

In their study, [78] found that instructors have identified some of the pitfalls that surround MOOCs. These pitfalls included pedagogical limitations. MOOCs programmes are joined by many students from various countries across the globe. This situation brings about a challenge of teaching students from various backgrounds such as educational, national and cultural. Also, MOOCs are resource intensive programs. Appropriate policy framework must be in place to ensure that required resources are provided. Sufficient support must also be provided to staff teaching in MOOCs programmes. It has been pointed out that they need skills to improve their competencies, conducive environment to boost morale in order to enable them to cope with challenges of teaching MOOCs programme, especially online assessments. There are challenges of interoperability. The online assessment tools need to be integrated into LMS of institutions so that data exchange can occur seamlessly. Also institutions may need to exchange data [79].

6. Future of online assessments

With the proliferation of MOOCs, online assessment remains a crucial part of the system to support e-learning. Since the challenge is how to conduct authentic and credible assessments especially in the online systems, then the ability to provide and secure assessments remain key. Such security will inject credibility into the examination process and hence trust in the results, thus promoting trustworthiness of online education. Zakharova and Tanasenko [78] assert that MOOCs can be attended by hundreds and thousands of learners. This increased number makes it difficult for students to be assessed in a normal manner as assessment cannot be done by the instructor. Therefore, the use of automatic assessment tools become necessary, and the fact remains that online assessments are here to stay.

The future will see more features of secure online assessment systems such as proctoring features, lockdown features, authentication options, webcam features, the interaction between the examinees and the test administration, analyzing the testing events instantly, and evaluating the level of security risk by taking advantage of existing data sources such as demographics, test stakes, and testing history, and overall security capability. The success of these will also draw attention to authentication methods that go beyond biometrics-based authentication and draw on artificial intelligence techniques. Economies of scale will drive these developments as institutions and MOOCs champion their business models that support anywhere, anytime, any device learning, teaching and assessment.

The gap yet to be filled in order to provide that credibility and trustworthiness of online education, is narrowing due to private and commercial education providers entering the space and are providing tools that can be used to proctor the assessments. However, current proctoring technologies are expensive. The demand for additional equipment such as cameras or cellphones/tablets makes the technology

neither widely applicable nor accessible. Although systems that observe behavior of students are reported by Indi et al. [43], there is still needed to develop systems that are fully automated and artificial intelligence-driven that use only the camera and the microphone that come with the basic laptops. Such systems will make online assessments complete and accessible to everyone. MOCCs and hybrid systems will further benefit from such systems.

Studies conducted by many researchers have discussed the effectiveness of applying technology in education. Studies further showed that this effectiveness can be achieved if factors affecting the perceptions of students and teachers in its use and their experience in an online learning set-up are examined [80–85]. A dominant characteristic of the investigation has been the appetite of students for online assessment. Online assessment has also created new challenges for academic integrity, and this has in part driven the refocus on assessment design in order to provide assessment that is robust in the face of the increased challenges in online environments, and in particular from commercial companies that provide opportunities for academic misconduct online. As the threat of the COVID pandemic declines, the new normal in assessment in this large-scale international higher education system, the new paradigm for pedagogic approaches to authentic assessment, technology-inspired academic practice, and the universities' commitment to academic integrity.

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Section 3

Education Policy

Blockchain in Higher Education: A Secure Traceability Architecture for Degree Verification

Daniel Chiş and Mihai Caramihai

Abstract

College fraud, driven by the demand for diplomas in the labor market, has become a pervasive global phenomenon. This multi-billion-dollar industry poses a significant challenge, as almost every employer is susceptible to encountering fraudulent diplomas. The lack of transparency in the accreditation process and university data systems necessitates trust in intermediaries, including students, faculty, and university officials, to verify the legitimacy of credentials. However, this trust-based system leaves room for errors and fraudulent activities, leading to the proliferation of fake diplomas. Blockchain technology emerges as a potential solution, promising trustless and transparent systems that eliminate the need for intermediaries or central authorities in transactions between strangers. By leveraging blockchain, a distributed digital platform can be developed, fostering integrity and trust among participants from different industries. Within the context of certificate systems, blockchain offers the means to establish a secure and tamper-proof record of credentials. Each certificate or diploma can be digitally signed and stored on the blockchain, ensuring its authenticity and preventing unauthorized modifications or forgery. This enables direct access and verification of credentials by employers, bypassing the reliance on potentially untrustworthy intermediaries.

Keywords: blockchain technology, educational sector, educational certificates, fraud prevention, fake diploma problems

1. Introduction

Blockchain technology is a transformative innovation with applications across various industries. Initially introduced in 2008 as the underlying technology for Bitcoin transactions, blockchain has since evolved to offer benefits beyond cryptocurrencies. Its primary goal was to enable direct transactions between users without the need for intermediaries. In essence, blockchain operates as a decentralized network of interconnected data blocks, protected by cryptographic techniques to ensure security and prevent tampering. Each node within the network maintains a transaction log, verifies and records transactions, and cross-checks its own record with others in the network to maintain consistency and integrity [1, 2].

Blockchain operates in a decentralized manner, eliminating the need for a central authority and relying instead on consensus among network participants. Each node within the network maintains a copy of the entire blockchain or relies on lightweight nodes for blockchain data. As new blocks are added, the blockchain data grows, and once added, data cannot be deleted without the agreement of network participants. Blocks are interconnected, with each block containing the hash of the previous block, ensuring data integrity and protection against tampering. Modifying data within a block alters its hash, making any changes easily identifiable [2].

The blockchain structure, as depicted in **Figure 1**, comprises a header block and transaction data. The header contains elements such as the hash of the previous block, timestamp, Merkle root of transactions, difficulty, and nonce [2]. The transaction data holds all the transactions within the block. The genesis block, being the first block, does not have a previous block hash. All blocks can be traced back to the genesis block for verification purposes.

Each block has a specific storage capacity, and once filled, it is closed and connected to the previously filled block, forming a data chain known as a blockchain. New information is added to a new block once the previous block is complete. Blockchains are designed to be resistant to data modification [3].

Blockchain is a decentralized public network that can store and verify records, which is a necessary requirement in the education system for transcripts and other authentication certificates used for employment purposes. It offers several features that can streamline various processes in educational institutions. The main features of blockchain, as outlined in [4], include decentralization, immutability, security,

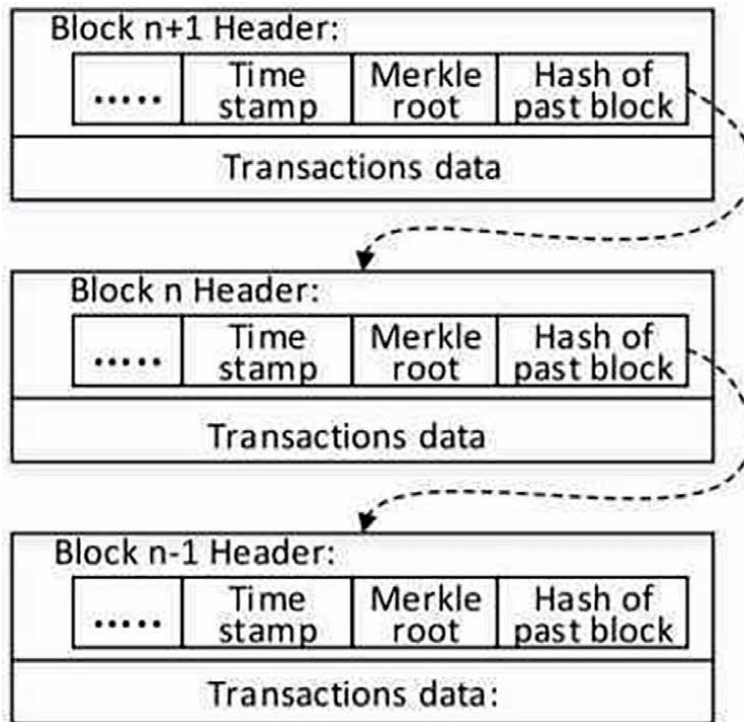


Figure 1.
Blockchain structure [2].

smart contracts, payment registry, and transparency. These features contribute to the reliability, efficiency, and transparency of educational record-keeping and verification processes.

Blockchain possesses several notable features that have contributed to the success of Bitcoin. These features, as outlined in [2], include:

1. **Data redundancy:** The blockchain can store identical data from multiple nodes simultaneously. If a node loses its data, it can be recovered from other nodes that have a copy of the blockchain, ensuring data integrity and resilience.
2. **Data integrity:** Any change made to a block is reflected in the hash of the subsequent block. This makes it easy to detect any alterations in the data since any change in a block will affect the hash of subsequent blocks.
3. **Transparency:** The blockchain's data is stored on complete nodes, allowing anyone in the network to view the activities recorded in the blockchain. This transparency enables fraud detection and enhances the accountability of public services.
4. **Decentralization:** Blockchain eliminates the need for intermediaries, resulting in autonomous systems that operate without central authority. This decentralization also removes associated costs and allows for more efficient processes.
5. **Efficiency:** By eliminating intermediaries and streamlining processes, blockchain enhances the efficiency of various systems and transactions.
6. **Interoperability:** Blockchain provides a platform for data sharing and synchronization of services, enabling interoperability among different entities and systems.
7. **Data verification:** Blockchain enables easy verification of data authenticity, such as through the use of digital signatures, ensuring the originality and integrity of the stored information.

These features make blockchain a powerful technology with applications beyond cryptocurrencies, including in the field of educational record-keeping and authentication.

Blockchain technology has the potential to revolutionize the field of education by enabling secure verification and sharing of educational credentials and qualifications. Its features of interoperability, transparency, and data integrity make it a promising tool in this context.

In the education sector, blockchain can be used to issue, transmit, share, and verify educational qualifications and experiences [5]. By leveraging blockchain's interoperability and portable accreditations, students can have access to their competencies and certification documents from anywhere in the world.

The use of blockchain in education helps reduce fraud, streamline the hiring process, and minimize bureaucracy. It gives individuals greater control over their own data and enables instant and secure validation of qualifications and characteristics. Blockchain serves as a common and trusted source of truth, ensuring the authenticity and security of educational records.

Although the adoption of blockchain in education is still in its early stages, some institutions have already started utilizing it. For example, the University of Nicosia became the first university to certify its degrees through blockchain [5]. These early adopters aim to validate and share academic certificates and student results.

Blockchain technology also holds potential for improving teaching and learning processes. It could facilitate collaboration and partnerships among educational institutions, allowing for the sharing of information about individuals' academic studies. Smart contracts, a feature of blockchain, could streamline administrative processes and provide students with access to a wider range of educational programs. This, in turn, has the potential to increase the pass rate and decrease the dropout rate. Additionally, the use of a common infrastructure through blockchain can help reduce operating costs [1].

Overall, the use of blockchain in education is still evolving, but it has the potential to bring significant advancements in credential verification, data security, and collaboration among educational institutions.

There has always been fraud in academic records. Some studies state that a multitude of degrees are purchased annually. It often happens that individuals can buy fake diplomas from real schools or schools that can be called diploma factories. Another common problem is the modification of academic records to the advantage of the professional gain of the respondents.

Fraud can be avoided through the blockchain, so that students' credentials are protected from illegitimate access and modification. In this sense, cryptography is used in combination with digital signatures to validate the origin and recipient of a document. Changes to an accreditation can be viewed via the blockchain by modifying the hash and can be validated by the issuing organization. The termination or expiration of some credentials can be done instantly.

There are many studies that try to demonstrate the usefulness of blockchain technology in education. One of them, called the Blockchain in Education report by the European Commission, points out that the blockchain can be used to meet a number of challenges, such as accreditation, digital certification, transferring credit to students or making payment transactions for students. The study mentions that blockchain applications in the educational field are still in their infancy and still do not reach all the proposed objectives, are not completely safe and do not eliminate blockages of any kind. However, we can conclude that the interest for this type of application is growing. As mentioned in [6], MIT (Massachusetts Institute of Technology) released 100 digital diplomas to graduates through a pilot project. This project focused on issuing digital certificates.

1.1 Analysis of current state-of-the-art of European Digital Recognition using blockchain in comparison to best practices in the world

There is no official information on the adoption of blockchain technology at European level in an organized and regulated framework, the examples specified in the paper are small initiatives, but with great potential.

1.2 Malta

Since the beginning of 2017, Malta has started to implement a pilot project to store and issue blockchain certificates. Currently, the project includes all academic entities in Malta.

1.3 Spain

Spain has faced several cases of fake university diplomas. This topic came to public attention in 2018 when Cristina Cifuentes (the former president of the Community of Madrid) was accused of falsifying her master's degree diploma. As a result, the Red Blue project was born. It aims to validate diplomas and certificates using blockchain technology. According to [7], in December 2019, a number of 76 universities were involved in the project.

One of these universities is The University of Murcia, which recently has organized sessions on topics such as Artificial Intelligence, Cloud, Internet of Things, Data Analysis, and Big Data. Following this event, the University issued blockchain certificates to the participants. This initiative aims to promote the use of blockchain technology in general activities [8].

Certificate holders can access and import it using the Blockcerts application. On the official Blockcerts page [9], the application is described as “an open standard for creating, issuing, viewing, and verifying blockchain-based certificates. The digital records are registered on a blockchain, cryptographically signed, tamper-proof, and shareable”.

1.4 Germany

A technical university in northern Germany, the Technische Hochschule Lubeck, is involved in a publicly funded project called the Digicerts Project. The goal of this project is to use blockchain technology to store student certificates, an upgrade from the current centralized database. At the end of the project, the certificates could be accessed and managed securely by the university, students, and companies—potential employers of students. Thus, the cases of forgery and lying regarding the accreditations will be minimized. In addition to storing certificates, blockchain technology would be used to manage and schedule exam sessions [10].

1.5 Estonia

Estonia is known as one of the most digitized countries in Europe. Its citizens can pay, sign, request official documents in various public sectors such as administration, health, transportation, etc. This digitization is based on well-developed and respected legislative regulations.

Although blockchain technology is not currently used in higher education in Estonia, the country's prestigious technical universities offer courses for learning and researching blockchain concepts. These courses are taught in technical programs, but do not have a 100% focus on the blockchain. They are currently working on a specially developed curriculum for blockchain technology, which will prepare future engineers for ambitious and innovative projects.

1.6 India

India aims to increase enrollment in primary and higher education by 2030. This will be achieved by developing a Digital Education Ecosystem. This digitization involves the adoption of blockchain technology for storing notes, activities, certificates, diplomas, attendance, and much more. Educational institutions, potential employers, and certification agencies will have access to this ecosystem through integration [11].

1.7 United States

It can be said that MIT was the first educational institution to use blockchain technology to store and verify certificates. From a pilot project, Blockcerts, the open-source program for storing digital certificates, was born in 2016. Because Blockcerts is open source, this solution was quickly adopted by other US universities, which favored digitalization at a broad level.

1.8 Canada

McMaster University in Hamilton, Ontario, created its own Blockcerts issuing system, which issues certificates for graduated students. The Canadian Colleges Association also declared that it is partnering with a private company to create a record-keeping system with blockchain technology that will be used nationally in higher education.

According to [12], the implementation of blockchain technology in higher education is also present in the Middle East, North Africa, Pacific Asia, Latin America, and the Caribbean.

2. Methodology for collecting data

2.1 Objectives of the study

The main objective of this chapter is to present the advantages of adopting blockchain technology vs. the Higher Education diploma/certificates management. To achieve this, we have started with questionnaires to students from a technical university (i.e. University POLITEHNICA Bucharest) to gauge their familiarity with blockchain concepts and gather their opinions on implementing this technology. Additionally, interviews have been conducted with education and IT experts to explore the advantages, disadvantages, potential applications, and specific needs related to adopting blockchain in the education sector. By gathering insights from both students and experts, the study aims to determine their perspectives on the topic and contribute to understanding the potential adoption of blockchain technology in Higher Education starting from a double perspective: that of the beneficiaries (students) and that of the implementers (IT experts).

3. Development of hypothesis vs. questionnaires/interviews

For this study, we have developed six hypotheses, also represented in **Figure 2**, regarding the use of blockchain in higher education, which also capture the possible advantages of this technology.

The hypotheses considered are presented below:

H1: The high level of security on which blockchain technology is based leads to improving the management of student's records.

H2: The high level of security on which blockchain technology is based leads to securing a collaborative learning environment.

H3: The management of student's records through blockchain technology contributes to a better control of data access.

H4: The collaborative learning environment that blockchain provides leads to improving learning performance.

H5: The management of student's records through blockchain technology implies lower costs for students.

H6: The efficient control of data access through blockchain technology implies lower costs for students.

The first hypothesis highlights the fact that security is a very important factor in terms of storing student certificates and diplomas, a factor that blockchain offers at a high level. Along with the growth of online education, the market for fraudulent certifications and degrees is expanding. For many corporations and educational institutions around the world, this is starting to become a big concern. In order to solve this problem, the institutions could register the certificates on the blocks as immutable entries, which would allow a blockchain to easily solve the certification management issue. Furthermore, in their email signatures, social media sites, and resumes, students can easily distribute these credentials by including the precise URLs.

The second premise presents how one of the most important characteristics of blockchain technology, high security, influences the eLearning industry. By its nature of protecting data, this application of blockchain creates a collaborative learning environment, where learning materials are verified and students are helped to develop their critical thinking and their communication accomplishments.

According to the third hypothesis, the management of students' records through blockchain facilitates data access. Thus, blockchain offers the students a digital identity. As a result, they have ownership of their records and can prove the authenticity

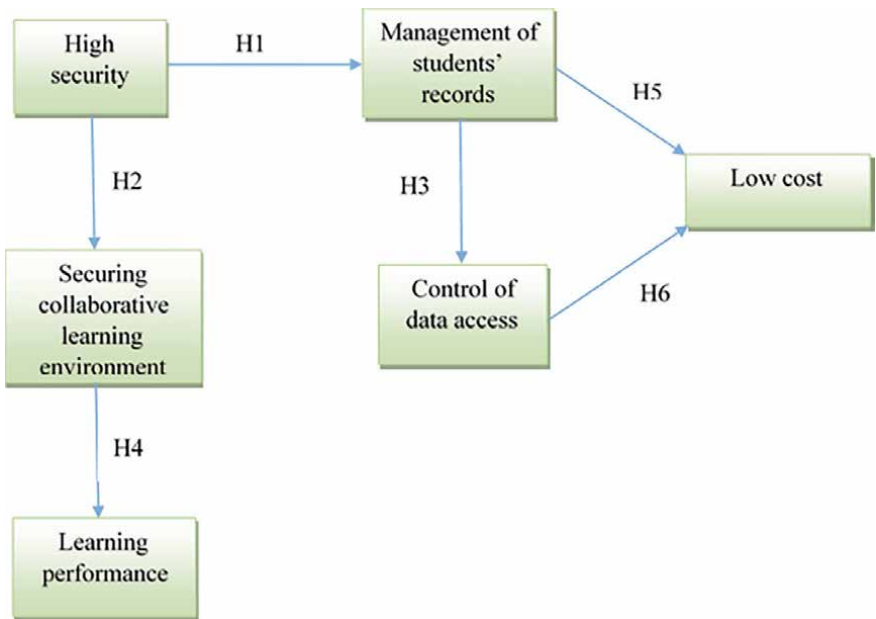


Figure 2.
The hypothesis structure.

of their academic achievements whenever needed. For instance, by allowing access to the blockchain, it is simple to transfer students' records when they transfer from one university to another.

The fourth hypothesis highlights the fact that, with the creation of collaborative learning environment in which students work together, emphasizing communication and interaction between them, learning performance increases. Blockchain technology has the potential to enhance collaborative learning by providing a secure and transparent platform for collaboration, evaluation, and credentialization. With its help, individuals develop not only new academic skills in academia, but also other important skills, such as social responsibility, critical thinking, communication, and teamwork, which are highly valued by employers.

According to the final two hypotheses, the digitalization of a student's documents, through blockchain technology, allows data access in an efficient manner, which reduces costs for students. This can be extended to circumstances where the records of students, who visit other institutes, as part of exchange programs, can be easily shared across institutes by granting the necessary access, which lowers the administrative costs.

4. Data analysis

4.1 Questionnaires

The questionnaire was completed by three groups of students of 49, 77, and 21 students each. Students follow bachelor's, master's, and PhD programs at University POLITEHNICA Bucharest/Automatic Control & Computers faculty. The questionnaire consisted of closed-ended, true-false questions in which students had to answer if they were familiar with some concepts regarding blockchain technology. The other type of questions consisted of 5-scale scales related to various scenarios.

4.2 Statistical and logical analysis

4.2.1 Statistical analysis

In the table below, the percentage elements resulting from the analysis of the questionnaires are presented in **Table 1**.

4.2.2 Logical analysis

Based on the table above, the following conclusions can be drawn about the students in the AC group:

- The terms that students are most familiar with are: Private Key, Validation Process, Wallets, Public Address, Mining, Cryptographic Hash Function, and Hashtable (all with a percentage of over 50%);
- Of the terms known by more than half of the participants in the questionnaire, Private Key, Wallets, Public Address, and Mining received the most positive answers;

I have already heard of:	YES	NO	N/A
Smart Contracts	38.8%	40.8%	20.4%
Multi Signatures	49.0%	30.6%	20.4%
Oracles	44.9%	34.7%	20.4%
Decentralized Storage	42.9%	36.7%	20.4%
Private Key	69.4%	10.2%	20.4%
Validation Process	67.4%	12.2%	20.4%
Blockchain Fork	36.7%	42.9%	20.4%
Hashpower	36.7%	42.9%	20.4%
Proof of Work (PoW)	42.9%	36.7%	20.4%
Proof of Stake (PoS)	38.8%	40.8%	20.4%
Block Reward	36.7%	42.9%	20.4%
Wallets	69.4%	10.2%	20.4%
Public Address	69.4%	10.2%	20.4%
Transaction Fees	63.3%	16.3%	20.4%
Blockchain Bloat	36.7%	42.9%	20.4%
Mining	69.4%	10.2%	20.4%
Cryptographic Hash Function	57.1%	22.4%	20.4%
Hashtable	53.1%	26.5%	20.4%

AC group responses in percentages vs the total number of responses.

Table 1.
Responses mapping.

- The least known terms are Blockchain Fork, Hashpower, Block Reward, and Blockchain Bloat;
- A relevant observation is the logical difference between the popular and the least known terms. The popular terms are known almost unanimously, only 10.2% of participants did not hear about them, while the least known terms are still familiar to 36.7% of the participants in the questionnaire.

Regarding the following aspects that students consider necessary before introducing blockchain technology in education, the following results were obtained:

- “*Involvement of Government, strict worldwide regulation*”—It was rated as necessary in an average of about 3 on a rating scale of 1 to 5.
- “*Everything has to be set up with open-source technologies*”—It is considered by most students an aspect that must be considered.
- “*The ability to get a copy of my own data that can be stored on my own node, regardless of which blockchain system was originally used*”—It was rated as necessary in an average of about 3 on a rating scale of 1 to 5.

- “The ability to operate a full node and store an encrypted copy of the blockchain used to store credentials”—It was rated as necessary in an average of about 3 on a rating scale of 1 to 5.
- “Involving corporations in the process of setting up Blockchain technologies in the educational sector”—It is considered by most students an aspect that must be considered.
- “In-depth education about blockchain technologies for IT professionals and administrative officers in the educational-sector”—He had an almost maximum number of pro votes.
- “The possibility to process information from various blockchain systems”—He had an almost maximum number of pro votes.
- “Clear and transparent rules about who is responsible for payment of fees”—It is considered by most students an aspect that must be considered.
- “Basic information/education about blockchain technologies for all people involved in the educational sector”—It was rated as necessary in an average of about 3 on a rating scale of 1 to 5 (**Figure 3**).

Students were also consulted on the suitability of blockchain technologies for different use cases in the educational sector. Thus, for the following cases it was considered that blockchain is very suitable (with an average of over 3 points on a scale of 1 to 5 where 1 is not suitable and 5 is highly suitable): “Competencies and learning outcomes management, Evaluating students’ professional ability, Securing collaborative learning environment, Protecting learning objects, Enhancing students’ interactions in e-learning, Supporting lifelong learning”. The cases for which votes are close to not suitable (with an average of less than 3) are: “Certificates management, Fees and credits transfer, Obtaining digital guardianship consent, Copyrights management, Allowing employers and other organizations to view student’ educational results and other qualifications on a blockchain” (**Figure 4**).

Among the students, a survey was conducted on the professions that require more knowledge of blockchain technologies, in terms of their use in the educational sector. Among the most voted professions, which require a great deal of knowledge in

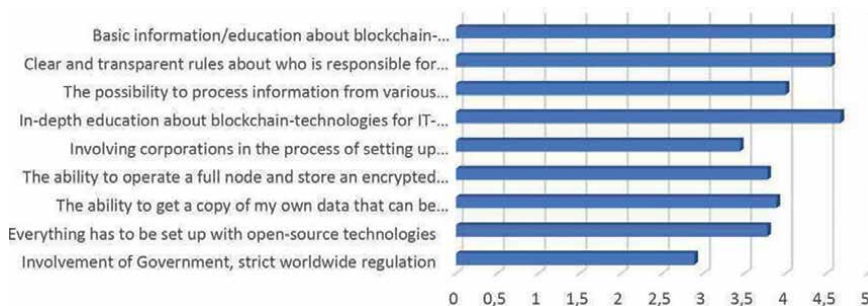


Figure 3.
“The following aspects are in my opinion necessary to consider before including blockchain technologies within the educational sector” Average of responses.

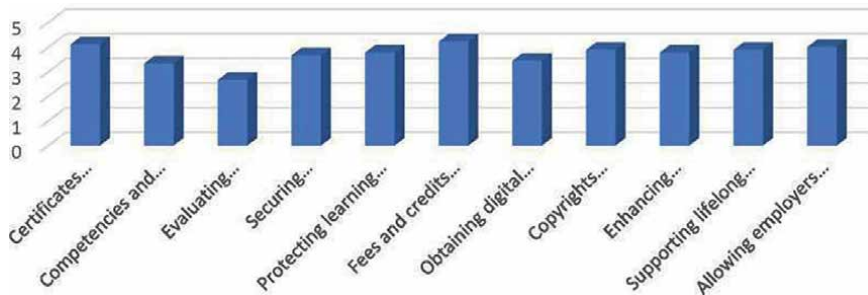


Figure 4.
 “In my opinion blockchain technologies are suitable (or not suitable) for the following use cases within the educational sector” Average of responses.

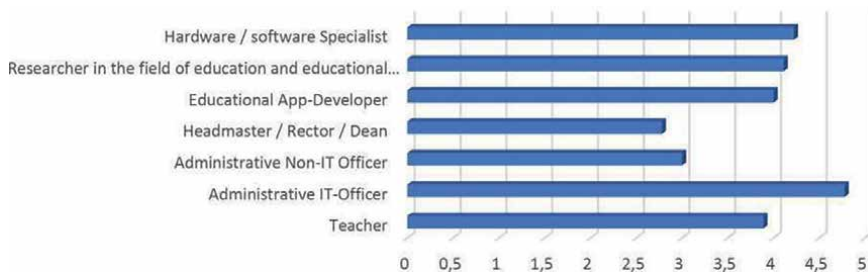


Figure 5.
 “Please rank which professions require lower or higher knowledge of blockchain technologies, regarding their use in the educational sector” Average of responses.

blockchain technologies are (with an average of over 3 points on a scale of 1 to 5 where 1 is no knowledge needed and 5 is high knowledge needed): “*Hardware / software Specialist, Researcher in the field of education and educational, Administrative IT Officer, Educational App Developer, Headmaster / Rector / Dean*”. Among the professions that do not require knowledge are: “*Teacher, Administrative Non-IT Officer*” (Figure 5).

The benefits of adopting blockchain technologies in education, considered important by students are: “*Enhancing learners’ activity, Supporting learners’ career decisions, Improving management of student’s records, Identity authentication, Better control of data access, Low cost, High security*”. The things that were not considered important benefits are: “*Enhancing trust, Enhancing students’ assessment*” (Figure 6).

Last but not least, an opinion poll was conducted on the challenges of adopting blockchain technology in education. As a result, the most voted challenges to consider are (with an average of over 3,5 points on a scale of 1 to 5 where 1 is not important to consider and 5 is highly important to consider: “*Privacy & security, Cost, Data unavailability, Scalability, Setting the boundaries, Trust*”. The following are not considered challenges to consider (with an average below 3): “*Immaturity, Weakening traditional school credentials*” (Figure 7).

4.2.3 Synthesis of results vs hypothesis

Following the analysis based on the students’ answers to the questionnaire, the results obtained are, to a large extent, corresponding to the hypotheses. When students from an IT university were interviewed, the expectations were higher in terms

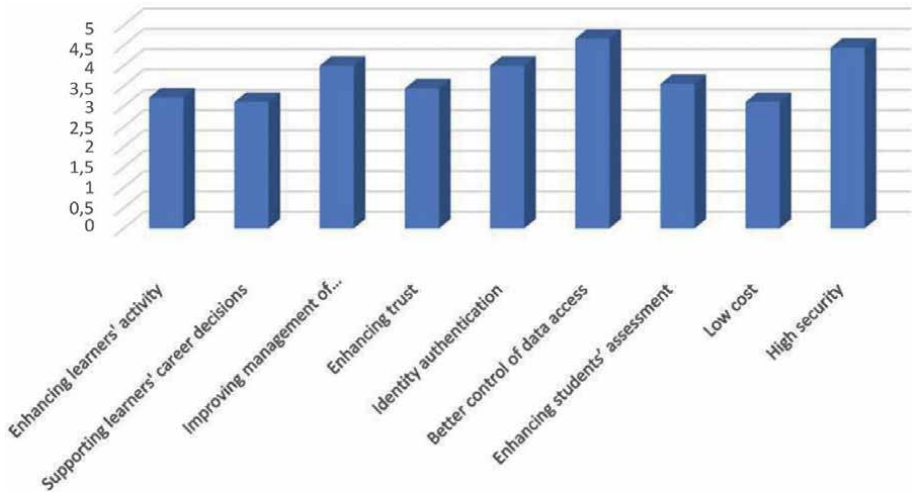


Figure 6.
“Benefit of adopting blockchain technologies in education” Average of responses.

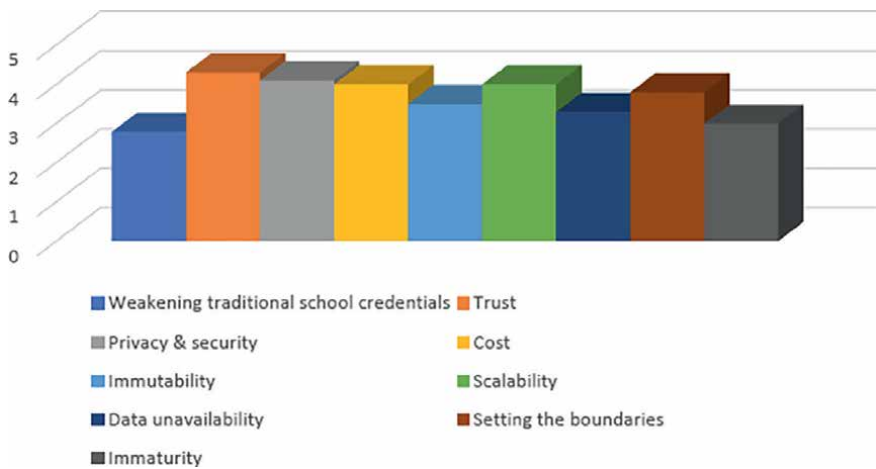


Figure 7.
“Challenges of adopting blockchain in higher education” Average of responses.

of popularity and knowledge of Blockchain technology. For the most part, less than half of the respondents heard about the terms mentioned, but there were also quite a few abstentions. Terms such as “Blockchain Fork”, “Blockchain Bloat”, or “Hashpower” are not well-known among students. However, the students responded positively to the integration of the blockchain in the educational field and considered the technology appropriate in many of the cases presented. Also, most students have been thrilled and support the benefits that blockchain can bring to education. However, I also agree that there will be many challenges in adopting blockchain technology in education.

Starting from the outcomes obtained in the previous section and from the hypotheses developed in Section 3.2., we are able to make a comparison between the two. Thus, we can strongly affirm that they are firmly related, the synthesized results validating the six premises formulated. In addition, both parts of the comparison

encompass the main elements through which blockchain can revolutionize the education industry: high security, data accessibility, transparency, interactivity.

4.3 Interviews

4.3.1 Centralization of data

Within the Boosting Sustainable Digital Education for European Universities project, seven interviews with experts were held. All the answers to the interviews were collected during January 2022, so all the opinions and suggestions offered can be considered relevant to the current context, which is extremely important given the dynamic nature and speed with which technology evolves.

The participants to the interview come from both public and private sectors, in the domain of education and information and communication technology, in management and executive positions. This diversity among experts will help to form an image as close to reality as possible regarding the use of blockchain technology in higher education. However, there was no participant working in a non-governmental organization. It should also be noted that all the experts interviewed work in areas related to the topic of the paper.

The interview consists of 11 sections, each section containing one or more questions. The questions are open, it is up to the expert how detailed or concise the answer may be depending on one's own experience and knowledge. Also, the questions are formulated objectively, so as not to influence the perception of the participants positively or negatively.

4.3.2 Statistical and logical analysis

Unlike the data obtained from the questionnaires, only a qualitative analysis can be performed on the data obtained from the interviews with experts. If tools such as Excel were used for the quantitative analysis of the questionnaires, the analysis of the interviews is done manually.

The participants in the interview have the status of experts, so their expertise, experience, and knowledge are unquestionable and officially recognized. Their answers are considered equally, but no quantitative conclusions will be drawn if there are discrepancies and disagreements between opinions.

In the next part of the chapter, the answers for each section of the interview will be analyzed:

1. "What are the potential applications of blockchain in higher education"?

All participants provided an answer to this question, listing possible applications of blockchain technology in higher education. The most popular answer was the storage and management of various documents such as student records, diplomas, certificates, scholarships, various academic, and scientific activities within university. One of the participants suggestively named this information Academic Passport, practically creating a digital identity for each student. Outside the university environment, this information may be available for the purpose of validating accreditations by employing companies.

Another identified use refers to research, the authors being able to publish and monitor the research papers, being able to see when it was cited or used in curricula. Thus, the decentralization of information can be achieved by preserving intellectual property.

Moreover, it has been suggested that cryptocurrency could be used both for tuition fees and for accessing research papers, a method by which researchers could fund their projects. It has been suggested that blockchain technology could improve the efficiency of administrative processes through smart contracts and funding tracking.

Other identified applications are tokenization of learning, developing Massive Open Online Courses and virtual universities. One of the participants found it necessary to introduce courses on blockchain technology of various levels of specialization and difficulty for bachelor's, master's, and PhD programs.

2. “What relevant data or units of learning would be on the blockchain”?

Experts have stated that sensitive or personal data is not stored in the blockchain. A common practice is to store a hash of the information for verification. This information would consist of smart contracts, academic records, awards, volunteer activities within university, research, certificates, diplomas, regulation, and security. The actual data will be stored on databases or other types of systems.

3. “One of the most critical components of a block on the blockchain is the quality of data, what are the quality assurance standards to ensure that the data is accurate, verifiable, and meaningful”?

The answers to this question varied: one participant did not know of the existence of such standards, three participants stated that the quality of the data is given by the consensus reached by the actors of the system, and three participants provided concrete examples of standards:

- ISO/TC 307/WG 2 Security, privacy, and identity.
- ISO/TC 307/WG 3 Smart contracts and their applications.
- ISO/TC 307/WG 5 Governance.
- ISO/TC 307/WG 6 Blockchain Use Cases.
- ISO/TC 307/WG 7 Interoperability.
- DIN. 3104:2019-04 Blockchain-Based Validation of Data.
- NISTIR 8202—Blockchain Technology Overview.
- ISO/TR 23455:2019 Blockchain and distributed ledger technologies

4. “What are some compelling reasons for using blockchain in higher education? Are there any reasons NOT to use blockchain in higher education”?

The reasons for adopting blockchain technology identified by experts are closely related to the applications listed in Section 1, namely the storage and administration of all documents related to student activity, use of cryptocurrency, and smart contracts, but also related to the benefits of blockchain technology: decentralization, scaling, security, transparency, and data integrity.

Another compelling reason is to familiarize students with a new and evolving concept, which has the potential to expand into many areas of activity. Thus, students will be able to meet industry expectations. Also, the implementation of such a technology translates into research, the development of specialized study programs, and the establishment of many jobs.

Moreover, 5 out of the 7 experts interviewed stated that they could not see a reason not to use blockchain technology in higher education. The specified disadvantages were the negative impact on the environment from the use of resources for computing power and storage. Although data immutability is considered an advantage, in some contexts it can be detrimental. The desire for change and the necessary resources were also marked as factors.

5. “What are the most significant hurdles that higher education will need to overcome before blockchain sees broad adoption”?

The main impediments reported by experts referred to the lack of legislative regulations, insufficient funding, and the need for training and research that may be affected by disinterest and inertia. From a legislative point of view, the use of blockchain technology is still a new field on which no national or European rules have yet been imposed. The EU’s General Data Protection Regulation could impose restrictions on the use of personal data, in the context in which the term personal data is still vaguely defined. Moreover, for an efficient implementation and functioning, there must be a good collaboration between entities (universities, private sector, the state).

In addition to the research and training needed to develop a system that uses blockchain technology, university staff must also be trained. They have different levels of knowledge and skills in the technical field, and the initiative may be met by lack of interest, desire, and even refusal to adapt. In any case, all the obstacles listed suggest that blockchain broad adoption will be a long and expensive process.

6. “With every new tech adoption that has broad implications, there are ‘winners’ and ‘losers’ who fall into these categories; Who are the biggest winners and losers? Does the benefit to the winners outweigh the impact on the losers”?

The conclusion reached by the experts is that the winners are companies and universities with enough capital to adopt blockchain technology from the beginning. The beneficiaries are both their business and their clients, in the field of education, health, and banking.

Although some experts have not identified any losers, others have referred to universities that cannot start the adoption of blockchain technology at the moment and will never be able to recover the lead that the top 50 universities in the world have. They also referred to possible jobs that will be canceled due to the development of technology.

All experts agreed that in the event of an effective implementation that follows a well-developed plan, the benefits will outweigh the disadvantages.

7. “Building on the previous question, there are potential equity, access, and accessibility implications, how do we ensure that blockchain does not marginalize these populations”?

Experts who could not identify losers to the previous question did not provide answers to this question. Those who identified the losers believe that the government should play an important role in ensuring equality and access. They also came up with solutions such as collaboration between the leading entities in the field who already have enough knowledge and experience and the entities at the beginning of the road. Partnerships and open-source resources should be encouraged.

In the case of people who have lost their jobs due to the adoption of blockchain technology, experts recommend helping them in professional reconversion through trainings and accessing European funds.

8. “Is blockchain in higher education just hype”?

Some experts have categorically stated that blockchain technology in higher education is not just a hype, and others have said that at the moment it is a hype, but in

the future, it may become a standard practice at a broad level. However, it takes time, investment, research, development of strategies, and government rules. The benefits of this technology, however, are undeniable, regardless of the current hype.

9. “Where do we go from here? Who needs a seat at the table”?

To begin with, more research and development of prototypes is needed to draw some general conclusions about the benefits, disadvantages, and impact that the adoption of blockchain technology will have. Experts believe that universities, governmental bodies, specialized EU institutions, research institutes, and the private sector should be involved. It can be stated that for an efficient implementation a good communication and collaboration between all the listed entities is needed.

10. “What are your observations about blockchain adoption in Romania in general and in the education field in particular”?

All the answers were offered in connection with Romania, and they varied according to the knowledge of each expert. Several companies and associations have been mentioned that aim to popularize and use blockchain technology. Technical universities have also begun to offer a range of blockchain-related courses and research opportunities. It should be noted that Romania is one of the countries that since 2021 is part of a project aims to issue diplomas and credits through the European Blockchain Services Infrastructure.

11. “How do you intend to check the relevant skills/competencies when recruiting for a dedicated project/job linked to blockchain application in higher education (in Romania)”?

Some experts would check the understanding of blockchain concepts through interviews and case studies. Others want to see previous experience with blockchain technology in the form of research or participation in similar projects. There are also experts who recognize that the field is far too new for people to have concrete skills, so they would look for people who have interacted with web development (backend and frontend), experience working with highly scalable products and cloud computing.

4.3.3 Synthesis of results vs hypothesis

All hypotheses were validated by the answers of the experts; indeed, they provided a wide range of examples for which blockchain technology can help in document storage and management, minimizing forgery, research, paying school fees with cryptocurrency, etc. Of course, they were able to identify the main obstacles, namely funding, lack of legislation, the desire of the entities to collaborate and the need for research and training.

Moreover, experts have encouraged the introduction of blockchain-related courses in bachelor's, master's, and PhD programs. They gave examples of companies currently working with this technology, but also of fields such as medicine and banking that have started and will continue to develop applications through this technology.

5. Development of a pilot model using blockchain concept for “record-keeping” of students’ degrees, certificates, and diplomas based on the previous analysis. Simulation of a case study

The figure below represents the architecture of a pilot model proposed for storing student records using blockchain technology. All activities performed by the user will be performed through an interface. In this case, the user can upload or request a file.

The files represent degrees, certificates, and diplomas. The documents in question can only be in pdf format. Each of these actions (upload & request) is performed with the help of smart contracts deployed on Ethereum Blockchain. The system works on a P2P network where each node has a copy of the Blockchain (**Figure 8**).

If the file is in a format other than pdf, the upload will be canceled, and if it meets the condition, the file will be stored in the document manager. Approval or rejection of requests is done through smart contracts. When one user sends a request to another user for a file, the smart contract will send a notification. Depending on the response received, the smart contract will notify the requester.

Digital certification solutions rely on digital signatures to achieve the issuance of certificates. Compared to electronic signatures that are easy to counterfeit, digital signatures allow the verification of a document so as to determine whether or not it was signed by a specific person. The digital signature allows the issuance of certificates so that a person personalizes his document with a stamp that can be generated only by him. Once signed, the document cannot be modified. Each person using a digital signature must have a document with an identity number called a public key and a connected password called a private key. When signing a document, its hash is combined with a person's private key to generate a unique code. The signature is printed on the document using the time stamp. The signature results from the combination of the two mentioned above, so it is unique for that document and can only be created by the person holding the private key.

In order to verify a digital signature, the public key of the person must be known. Public keys are codes that can be searched and found in public folders. The verification is performed by using the document and the public key. It is verified that the signature on the document is identical to the hash of the original document and that the signature is related to the public key of the person who signed the document. The whole mechanism is described in the **Figure 9**.

The next figure describes the use case in which a student enrolls in the undergraduate program (**Figure 10**).

The moment he/she is enrolled in college, he is issued a student ID. It is associated with a student record with personal information. The file is stored in the faculty database. In order to use blockchain technology to register the student, a blockchain address is generated, consisting of the public key and the private key, the unique address. The corresponding public key generated in combination with the student's ID is stored in the university database. Also, the confidential address issued is sent to

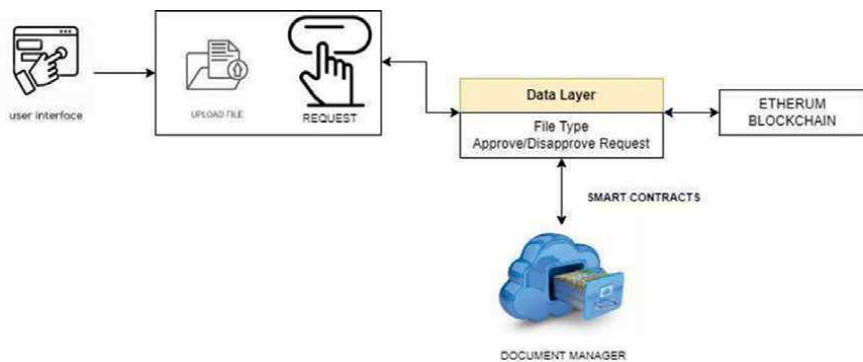


Figure 8.
Pilot model architecture.

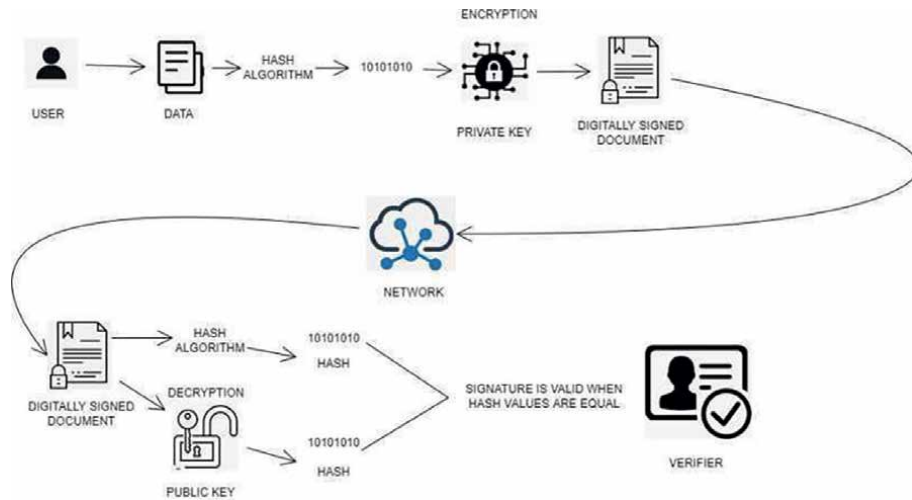


Figure 9.
Digital signatures.

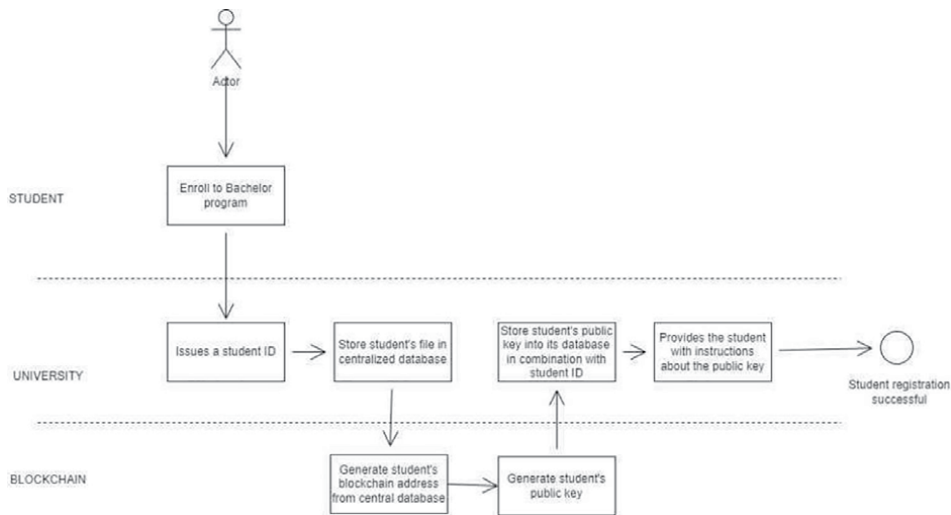


Figure 10.
Use case: student enrollment in a program.

the student, together with instructions for use. Thus, the student's registration was successful (Figure 11).

After the enrolled student successfully completes a course, he will receive a diploma as official proof that he has taken the course and has specific knowledge of the topic. The figure below shows the use case for adding the diploma to the student's digital academic passport. Firstly, the diploma is stored in the university's database. The blockchain address of the student in question is searched and the transaction is performed. There are two possible cases: the transaction is valid or not. The result of the valid transaction is the addition of the diploma in the blockchain so that it can be verified by any future employer.

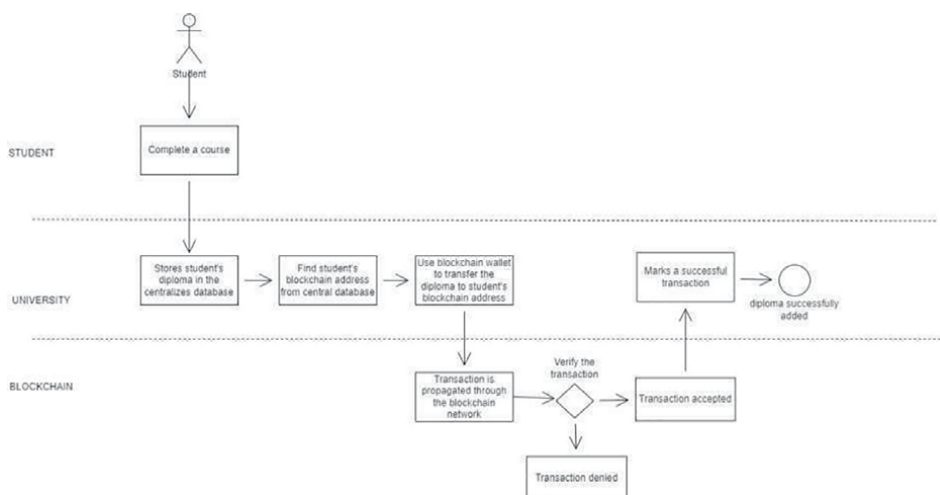


Figure 11.
 Use case: adding student's diploma.

6. Conclusions: a common framework of a European Digital Education Recognition solution

The advantages of using blockchain technology in higher education are undeniable: decentralization, scaling, security, transparency, and data integrity.

These benefits can potentially transform various aspects of education, including credentialing, record-keeping, and collaboration. However, there are also obstacles to consider:

Funding: Implementing blockchain technology requires financial resources for research, development, infrastructure, and ongoing maintenance. Securing funding can be a challenge, especially for educational institutions with limited budgets.

Lack of legislation: The legal and regulatory framework surrounding blockchain technology is still evolving in many jurisdictions. Clear guidelines and legislation are necessary to ensure compliance, privacy protection, and data ownership rights within the educational context.

Research, training, and development: Adopting blockchain technology in higher education necessitates research and development efforts to explore its potential applications and adapt them to the specific needs of educational institutions. Additionally, faculty and staff need training to effectively use and manage blockchain-based systems.

Integration with existing systems: Educational institutions often have legacy systems and processes in place. Integrating blockchain technology with these systems can be complex and require careful planning to ensure a smooth transition and interoperability.

Scalability: As blockchain technology gains adoption, scalability becomes crucial. Higher education institutions need to consider how blockchain-based solutions can handle a large volume of transactions and users without compromising performance.

User adoption and acceptance: Introducing new technology often requires a change in mindset and user behavior. Faculty, students, and other stakeholders need to understand the benefits and be willing to embrace blockchain-based solutions.

Despite these challenges, the potential benefits of blockchain technology in higher education make it an area of interest and ongoing exploration. As the technology evolves and matures, overcoming these obstacles will become more attainable, paving the way for innovative applications that can transform the educational landscape.

Finally, following the questionnaires and interviews with experts, it is indeed a common conclusion that blockchain-based educational certificates have several advantages in minimizing forgery and streamlining administrative processes in universities. Here are some key reasons why blockchain technology is seen as beneficial in this context:

Immutable records: Blockchain technology allows for the creation of tamper-proof and transparent records. Educational certificates stored on a blockchain can be securely verified, reducing the risk of forgery or alteration. This ensures the integrity and authenticity of the certificates.

Decentralization and data ownership: Blockchain-based systems can provide decentralized storage and management of certificates, eliminating the need for a central authority. This empowers individuals to have ownership and control over their own educational records, reducing reliance on centralized institutions.

Efficient verification processes: Verifying traditional paper-based certificates can be time-consuming and requires manual effort. With blockchain-based certificates, the verification process can be automated, reducing administrative burden and providing faster and more accurate verification results.

Enhanced security and privacy: Blockchain technology incorporates strong cryptographic mechanisms that ensure the security and privacy of data. Educational certificates can be stored securely on the blockchain, protecting them from unauthorized access or data breaches.

Interoperability and standardization: Blockchain-based solutions can enable interoperability among different educational institutions, allowing for seamless transfer and recognition of educational credentials. This streamlines administrative processes related to admissions, transfers, and job applications.

While there are challenges to overcome in implementing blockchain-based educational certificates, as discussed earlier, the potential benefits make it an attractive solution. The use of blockchain technology in this context has the potential to bring about significant improvements in certificate management, reduce fraud, and simplify administrative workflows in universities and other educational institutions.


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The Reimagined Approach to Promote the Use of Moodle in Teaching and Learning of First-Year Students

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Abstract

Teaching and learning in the contemporary era require technological or digital advancement. Various learning technologies offer a wide range of opportunities to enhance effective engagements between lecturers and students in institutions of higher learning. Consequently, this study explored the understanding of higher institutions in maximising the use of digital teaching and learning strategies to foster student success. In addition, the researchers investigated the proper provisioning of digital tools to successfully utilise online learning platforms. A total of 239 Science Foundation Students in the 2021 cohort participated in this study. A questionnaire with open and closed-ended questions regarding the availability of gadgets, university data provisions and network connectivity was administered. Results of this study revealed that 95 students had laptops while the rest used their smartphones, 52 students received university data during the investigation period and 186 managed to connect to the Internet mostly by utilising the university's free Wi-Fi. These findings have significant implications for the development of effective planning prior to the implementation of digital teaching and learning. Furthermore, results showed reasonable students' engagement regarding viewing quiz questions from the Modular Object-Orientated Dynamic Learning Environment (Moodle) platform and an ineffectiveness for the report posting exercises.

Keywords: digital teaching and learning, science foundation students, technological strategies, student success, blended learning, Blackboard, Moodle

1. Introduction

The umbrella term blended learning methodology is defined as a combination of traditional face-to-face and online computer-based lessons. It claims to redesign the learning environment to meet the needs of the present situation [1, 2]. de Brito Lima, Lautert and Gomes [3] exhibit that those educational practices associated with blended learning require discussion and experimental investigation. In most cases, blended

learning is implemented using diverse strategies for varied reasons such as data analyses and student engagement. Technological advancement has impacted educational practices, and to date, traditional classrooms are no longer constrained to conventional teaching methods [4]. Learning technologies offer a wide range of options to enhance the interaction between lecturers and students in universities [5]. However, being equipped with technology does not mean that students and lecturers can use it effectively [6]. Some institutions use their institutional learning management systems (LMS) as the leading technology for blended learning strategies [7]. Subsequently, LMS platforms such as Modular Object-Orientated Dynamic Learning Environment (Moodle) and Blackboard have limitations for analysing data [8]. Moodle is open source and is the most common LMS globally [9]. In addition, the platform is a widely tested, high-availability system, allowing students to log in and carry out their specific tasks [10].

Moodle array tools such as files, assignments and quizzes can be easily operated by users who do not have very advanced digital competencies [11]. For instance, Moodle quiz as a tool can support student engagement with learning through content flexibility and a variety of question types [12]. The provision of quiz questions in conjunction with automatic and timely feedback is a powerful means to foster learning [13]. According to Gamage et al. [14], active learning environment necessitates higher learning outcomes. Martín-Blas and Serrano-Fernández [15] indicated that quizzes are a valuable tool for students to test their level of knowledge.

On the contrary, historically disadvantaged institutions consider the Blackboard LMS as expensive.

The mission of this study is to develop an understanding of the reasons why institutions of higher learning are not maximising their digital teaching and learning strategies. Furthermore, this work aims to investigate a set of approaches that can hopefully lead to the successful use of LMS by the University of Venda, especially for first-year science foundation students. The latter will expedite early identification of at-risk students and further provide immediate support that may boost academic success [16].

2. Literature review

E-learning is the term that was coined following the emergence of new technology-informed education wherein the Internet is utilised to convey information [17]. Noteworthy, e-learning is achieved through the utilisation of electronic gadgets to enhance educational understanding [18]. Recognition of e-learning education gained popularity in higher education institutions (HEIs) sectors to set clear opportunities for critical and innovative thinking, and development of reasonable problem-solving capabilities [19]. However, it is important to note that e-learning's benefits extend to the workplace by assisting with the betterment of productivity and efficiency of employees [20]. The understanding must remain that the introduction of e-learning does not serve as a replacement for the education system, however, it is just enhancing the pedagogical approach by introducing easier ways of teaching and learning for creativity and innovation [21].

2.1 Moodle e-learning

Information and Communication Technologies (ICTs), in conjunction with learning management systems (LMS), enhance the instructional designs of educators. One platform, the Modular Object-Orientated Dynamic Learning Environment (Moodle)

platform; an open-source e-learning platform, provides creativity, communication and delivery; allows student and peer collaboration and various assessment activities [20]. Moodle is widely used by higher education institutions for the features it offers, for example, the creation of various online assessments, that is, quizzes, assignments, etc. Educators can upload their course contents, PowerPoint presentations, content animations and videos; all of which ease the workload on the educator; assist students learning; foster active communication *via* chats or group discussions, and hence aid the academic performance of the students [22].

Various learning management systems (LMSs) are used by different universities to develop, manage and distribute digital resources for face-to-face and online teaching and learning [23]. The University of Venda piloted and adopted the Modular Object-Oriented Dynamic Learning Environment (Moodle), as a learning management system (LMS) for improving, accelerating and enhancing tuition [24]. Most importantly Moodle fosters innovation, and pedagogically informed instructional design to increase student engagement [21].

The utilisation of Moodle poses a variety of merits as it allows students and academic staff to access and engage in a wide range of educational material [25]. Other advantages of Moodle are that students' and academic staff' engagement is in the real-time, easy platform to navigate through, keeping a register of grades and downloading the spreadsheets and easy creation of backup copies as well as information restoration [26]. Despite the merits of Moodle outlined by some scholars, Petrovici and Ciobanu [22] identified the disadvantages encompassed in the LMS. There are possibilities that students end up not studying what they were supposed to study when using Moodle. Most disturbingly, it becomes difficult for academic staff to assess the abilities and competencies of students for their creative and critical thinking capabilities. Furthermore, solving tasks can be achieved by copying and posting.

2.2 The role of ICTs in education

The incorporation of information and communication technologies (ICTs) in education has improved teaching and learning inside and outside the classrooms as well as revolutionised the teaching practices of educators. Information and communication technology (ICT) impacts the quality of learning, student engagement and student motivation in classrooms, [27]. "Using ICTs is essential in the teaching-learning process since many systems are used to disseminate knowledge, store and distribute information between students and teachers" [27].

Traditional education resources fall short of those compared to ICTs. A few examples of the usage of ICTs include: (i) Diverse information—access to a large amount of information online, is readily available. (ii) Instructional flexibility—students' learning occurs at their own pace and can revisit problematic areas online during their own time. (iii) Increased motivation and collaborative work—students are eager to work with ICTs as they can work on their own and love the creativity that ICTs provide them when doing group assignments [21]. (iv) Improved educational effectiveness: With the availability of educational resources and new ICT tools, educators can develop new and different teaching strategies to meet the needs of their students [23].

2.3 Background and significance of Moodle in higher education

Due to the coronavirus pandemic (COVID-19), higher educational institutions were globally brought to a standstill as lockdown restrictions were instituted to limit

the spread of the virus [28]. By the virtue of this pandemic wave, many institutions were compelled to transform from face-to-face to virtual teaching and learning digitally using different learning management systems (LMS). This change made digital media become a driving force for virtual learning. Digital technologies are now an integral view of the university students' experience used to enhance students' learning [29].

E-learning systems are increasingly enhancing an important part of the strategy for delivering online and flexible e-learning and the main advantage of e-learning is the opportunity for students to interact electronically with each other and their teachers [30]. Most universities officially adopted Moodle LMS. Moodle LMS is an open-source platform that is built on a collaborative pedagogical approach and offers a wide range of activities and resources, which support content management, e-assessment and online collaboration in various formats, which the user can implement and personalise according to their specific needs. Modern technologies compel higher education to set up to improve their teaching and learning approaches.

Challenges associated with the adoption and utilisation of Moodle by first-year students.

Though the use of Moodle LMS is advantageous, in South Africa, most first-year students are not covered by the method of technology-aided learning during their high school career, especially those from disadvantaged regions [31]. While more homegrown students are now getting into higher education than ever before, using technology-aided learning and teaching approaches introduces first-year students to a new and unfamiliar territory that could be excitingly experimental to some, but that can also act as an educational shock to others [32]. Furthermore, students who have never used digital instruments for learning had to switch overnight to virtual learning; this transfer placed them at a disadvantage. There is a need for higher education institutions to provide the necessary resources to facilitate the smooth assimilation of first-year students into their new environment.

3. Methodology

3.1 Study design

We hope to gain a deeper understanding of digital learning and teaching using the following research questions. Online learning activities are evaluated in terms of student engagement and performance. They assess digital tools' availability and use among students. Answering these questions can lead to insights and recommendations for improving higher education institutions' digital teaching and learning implementation and effectiveness. This is especially beneficial to students funded by the Science Foundation.

1. How are higher education institutions maximising digital teaching and learning strategies to benefit students?
2. What digital tools are available to students to use online learning platforms effectively?

3. Is there any information about how Science Foundation students use devices, data access and network connectivity?
4. When it comes to digital teaching and learning activities, especially quizzes and reports, how are students engaging with them?
5. How do the facilitation index and discrimination index compare across quizzes, and what lessons can be drawn from them?

3.2 Selection of participants

The study involved 239 Science Foundation students from the class of 2021. In this class, students were taught six different modules: Physics, Information Technology, English, Chemistry, Mathematics and Biology. Participation in the study was voluntary, and students' identities were kept confidential.

3.3 Methods of collecting data

A questionnaire was created that included questions regarding the availability of digital tools, the provision of university data and connectivity to a university network. To assess student Moodle usage, a summative test was developed. For this experiment, we developed an assignment quiz consisting of seven questions to engage students. The quiz questions consisted of multiple-choice, true/false, short answers and numerical. The quiz was opened on Thursday, 9 September 2021, at 5:20 PM, and closed Friday, 10 September 2021, at 5:20 PM.

3.4 Data analysis

A spreadsheet was used to analyse data regarding laptops, smartphones, Internet connectivity and university data provision. Analysing student engagement, activity views and post-test feedback provided insight into the use of the Moodle LMS for a summative physics test. An assessment of the effectiveness of the LMS in supporting student learning was accomplished through the use of statistical parameters, such as the facility index (FI) and the discrimination index (DI). The facility index (FI) was used to find the most straightforward question for students and is calculated using [14]:

$$FI = 100 * \frac{\overline{x_i}}{x_{i(\max score)}} \quad (1)$$

where $x_{i(\max)}$ is highest score in each question, $\overline{x_i}$ is the mean score.

The discrimination index is a measure of how the good students are doing versus the poor students on a question and is given by [33, 34]. In this study, the discrimination index was used to find the correlation between the score for individual questions and the score for the whole quiz and was calculated based on the following equation:

$$DI = \frac{\overline{G} - \overline{P}}{\max score} \quad (2)$$

where \overline{G} is the mean score obtained by the good students, \overline{P} is the mean score obtained by the poor students and the max score is the maximum score of the quiz.

4. Results and discussion

4.1 Provision of digital tools

This section reports the findings regarding the availability of data, laptops and Internet connectivity. **Figure 1** displays the availability of digital teaching and learning tools. As depicted on the graph, 95 students had laptops, and the rest had none. The findings of this study are congruent with the study conducted by Reisdorf et al. [16] who elucidated that the unavailability of laptops hinders class participation and flexibility in online tutorials.

Subsequently, 186 students did not have a problem with connectivity, while only 53 students experienced connectivity challenges. It is evident that since most of the students were on campus, Internet connectivity was mainly university Wi-Fi that is all over the campus. It was disadvantageous for off-campus students since they do not have university Wi-Fi at their respective residences.

With respect to university Internet data, only 52 students receive data during the investigation period. This has been exacerbated by the students' change of contact numbers without informing the institution. The number of those who did not receive Internet data is equal to those who experienced network connectivity, with the exception of one student who did not receive Internet data. In the same vein, of 95 students with laptops, 43 of them did not receive Internet data.

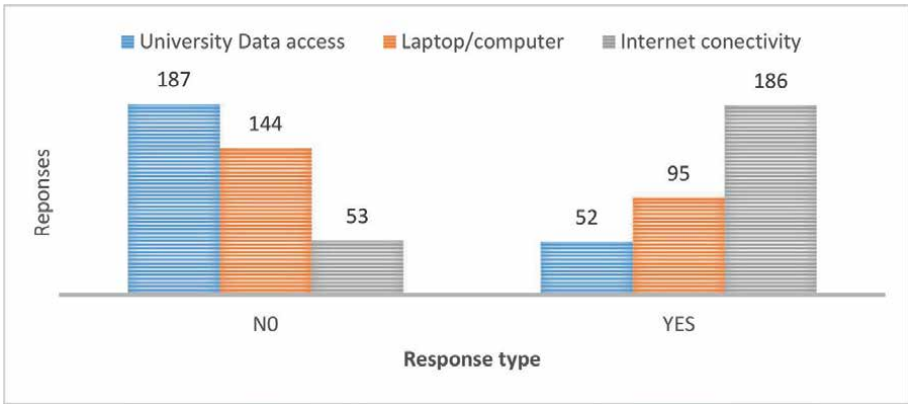


Figure 1.
Availability of digital tools.

4.2 Assessing the use of Moodle by science foundation students

4.2.1 Moodle induction to students

To access Moodle LMS, students were advised to use one of the two available login options, as shown in **Figure 2**.

The Microsoft login option was the most preferred since many students activated their Microsoft accounts. Microsoft login uses studentnumber@mvula.univen.ac.za followed by a given access password. Once a student has logged in, his or her name will appear on the top right corner of the page. In addition, on the very same page, a module code and introduction are displayed, as shown in **Figure 3** the introductory



Figure 2.
 Moodle login options.

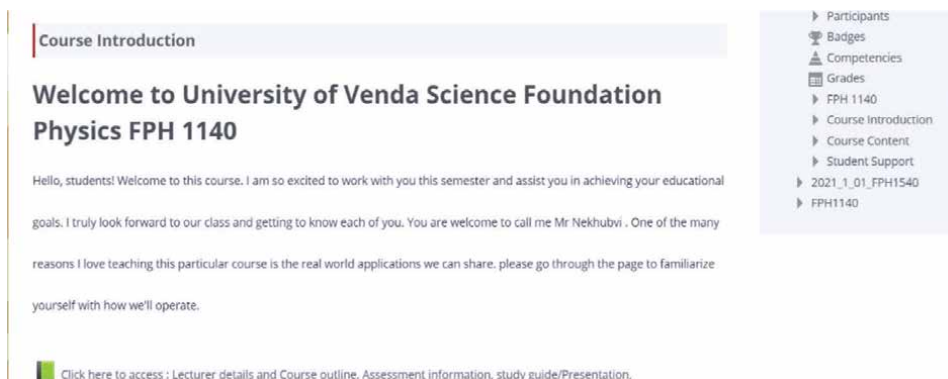


Figure 3.
 Course code and other details.

section, click here to access: Lecturer details and Course outline. Assessment information, study guide/Presentation.

4.2.2 Teaching and learning activities on Moodle

Higher education institutions (HEIs) are essential part of country's educational advancement. Furthermore, they are mandated to enhance critical thinking and problem-solving opportunities [19]. Therefore, implementing the mandatory usage of Moodle LMS to teach and assess students may benefit this rural-based institution. Microsoft PowerPoint presentations containing voice-recorded slides were uploaded on the Moodle LMS for students' use on a daily basis, as shown in **Figure 4**. The time allocation for each prevideo lecture is less compared to live lectures [35] hence, offer benefits to students. The benefits include but are not limited to revisiting lectures, flexible to attend classes or adjusting the speed of lectures arbitrarily [36]. In addition, an announcement plugin was used to send an email to students informing them about the availability of scheduled lectures to engage students.

4.2.3 Activity views and post report

Figure 5 shows all activities (views and posts) from the 9th to 16th of September 2021. As of the 9th of September 2021, the recorded number of student views and posts was 2085 and 139. On the 10th of September 2021, student views and posts were 9332 and 139. The number fluctuated from 11th until the 16th of September due to lecture viewing as well as quiz submissions.

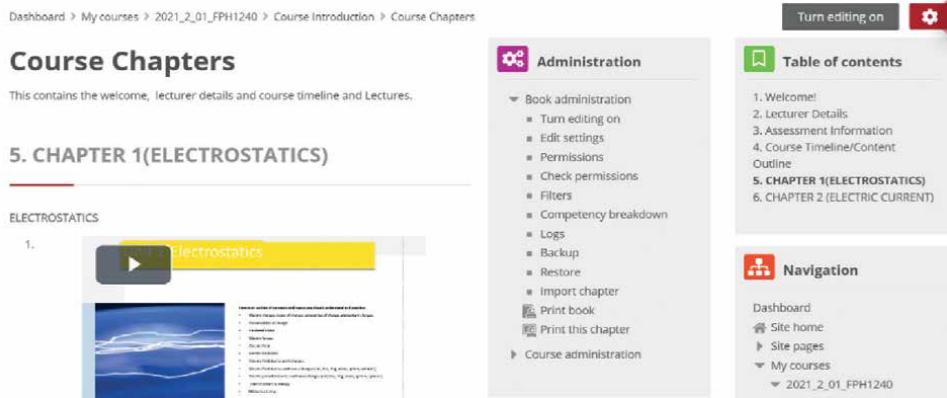


Figure 4.
Microsoft PowerPoint presentations containing voice-recorded slides.

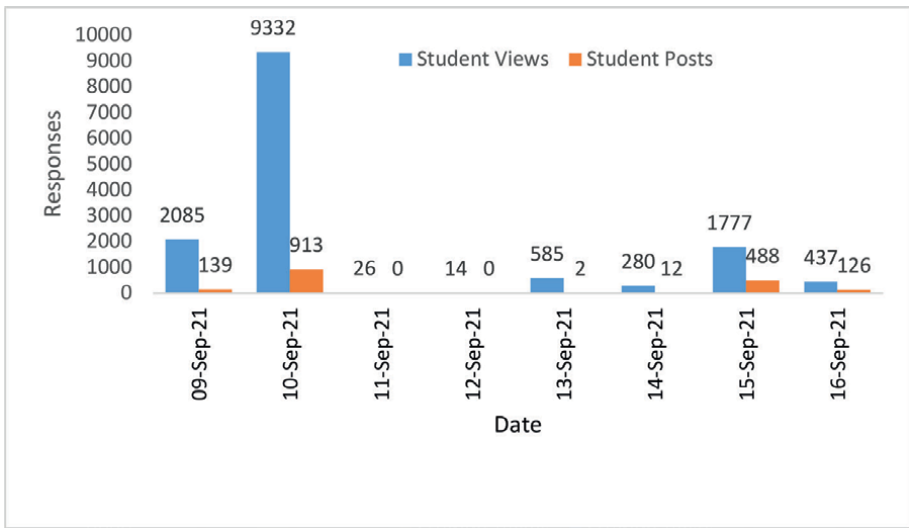


Figure 5.
Activity views and posts by students.

4.2.4 Assessment performance report

The quiz was opened on Thursday, 9 September 2021, at 5:20 PM, and closed Friday, 10 September 2021, at 5:20 PM. In addition, the statistical quiz report on the Moodle LMS was recorded to view students' progress, as shown in **Table 1**. Within the 24 hour period, we recorded 233 (95%) attempts by students.

The statistical quiz report consisted of parameters such as facility index (FI) and discrimination index (DI). Question 3 was multiple-choice and the most straightforward question for students with a 98.64% facility index. On the other hand, Question 7, which involved calculation, was the most challenging for students with a 33.15% facility index. The reasons for this performance seem to be computer illiteracy, and incompetence in the use of Moodle symbols in responding to the question. Based on the DI, the correlation between the score for individual questions and the score for the

Question number	Attempts	Facility index (%)	Standard deviation (%)	Discrimination index (%)
Q1	233	66.30	47.33	48.04
Q2	233	73.10	44.41	43.55
Q3	233	98.64	11.59	6.31
Q4	233	47.83	50.02	58.20
Q5	233	41.03	49.26	73.47
Q6	233	60.05	49.05	53.15
Q7	233	33.15	47.14	63.97

Table 1.
Statistical quiz report.

whole quiz is 73.47%. The latter means that students who scored highly on Question 5 are the same students who scored highly on the whole quiz.

5. Conclusions and recommendations

Considering the information provided, we can make several conclusions, including that Moodle is a valuable educational tool for undergraduate science students, that they use Moodle, and that they contribute to Moodle. Using this information, online learning can be concluded to be an opportunity and a challenge in educational settings.

In the study, digital tools are found to be a crucial requirement for students. Among the comprehensive students, only 95 had access to laptops, while the remainder did not. It is likely that those without access to laptops will have a significantly negative learning experience because of this significant discrepancy in laptop availability. To facilitate online learning, laptops are essential for students to access course materials, participate in virtual classes and complete assignments. In addition to making participation in class difficult, students' ability to participate in online tutorials may also be limited. The importance of providing equal access to digital tools for all students should, therefore, be addressed by educational institutions.

A reliable Internet connection is also crucial for effective online learning, according to the study. Almost all students, especially those on campus, had access to the Internet *via* the university's Wi-Fi network. In contrast, students living off-campus faced difficulties accessing the university's Wi-Fi since they did not have access to university Wi-Fi. Students off-campus may experience difficulties accessing online learning resources, participating in virtual courses and submitting assignments when they lack a reliable Internet connection. The university should offer mobile data plans or support local Internet service providers in order to ensure equal access to online education.

A study shows that Moodle users preferred the Microsoft login option for accessing the learning management system (LMS). Since many students already had Microsoft accounts activated, this preference is understandable. Students who used Microsoft login could access Moodle using their email address and password. Having a simpler login process increases usability and facilitates access to Moodle. Student user experience can be improved by integrating user-friendly login options into LMS platforms at educational institutions.

The article also highlights Moodle's use in teaching and learning. To provide students with an alternative to live lectures, Microsoft PowerPoint presentations with recorded slides were uploaded daily to Moodle. There were several benefits to these pre-recorded lectures, including revisiting lectures later, adjusting attendance requirements and adjusting lecture pace. It is possible to improve the learning experience by incorporating multimedia elements such as voice recordings, which can cater to the learning styles of different students. Students were also actively involved in the learning process by using an announcement plugin in Moodle to notify them about upcoming lectures. By using this real-time communication tool, students stay informed of course-related updates and events.

Through activities and posts on Moodle, the study also explores student engagement and participation. 9–16th September 2021 saw a variety of activity levels. Based on fluctuations in viewing lectures and submissions of quizzes, it indicates that students are actively using Moodle for course materials and exams. Lecturers can identify areas that require additional support or intervention by monitoring and analysing activity views and contributions. For an active online learning community, teachers must encourage active participation and regular interaction on the Moodle platform.

Finally, the study involves a quiz on Moodle. A high participation rate was recorded: 95% of students attempted the quiz. The quiz performance statistics included parameters such as facility index (FI) and discrimination index (DI) for each question, providing valuable insights into how students performed. Multiple-choice questions (Question 3) were well answered by students, whereas calculation-based questions (Question 7) were problematic. These performance variations can be attributed to factors such as computer illiteracy and inability to use Moodle symbols. As a result, the findings emphasise the importance of digital literacy, as well as the need for educators to provide adequate support and resources to students so they can enhance their technical skills. These challenges can be addressed, and online tools can be used effectively to improve student performance and learning outcomes.

The rigorous and timeous training should be mandatory for all the students and staff to ensure the maximum utility in all the programmes. The E-learning practitioners should constantly monitor and evaluate the minimal online presence of the students. The distribution of the gadgets should be done early and yearly to the first entrants at the institutions of higher learning in South Africa.

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Section 4

Creative Technology

Challenges of Usability of E-Solutions in Reimagining Education in Nigeria

Grace O. Aziken and Richard O. Oveh

Abstract

E-learning has been a main disruption in teaching and learning in the world, which has no doubt changed the narratives in the education sector. The advancements in the field of information and communication technologies have been a huge leap in the development of e-learning and presented a novel approach to education, with the switch from the conventional learning environment to transfer of knowledge online. During and after the COVID-19 pandemic it became imperative for more institutions of learning to adopt it. Despite the undeniable benefits of e-learning, usability has become the bane of its smooth implementation. This chapter highlights challenges associated with e-learning solutions and buttress the fact that usability will go a long way to give both teachers and learners a good user experience and give e-learning its pride of place in disruptive technologies. To successfully re-image education, more attention should be focused on ensuring usability of software solutions.

Keywords: education, COVID-19, e-learning, usability, user experience

1. Introduction

Education is key to improving productivity and overall development in any nation. This makes it mandatory that every nation invests in the education of its citizens. Also levels of education is a veritable tool to distinguish between developed and developing nations. The conventional environment for learning was a physical classroom, but with the introduction and advancements in Information and Communication Technology (ICT) electronic learning (e-learning) was developed [1]. E-learning is not a new concept, however it became popular during and after the COVID-19 pandemic when its implementation became a huge rescue to continue teaching and learning without physical contacts. Institutions at all levels were compelled to adopt e-learning or remote learning solutions in quick response to the lockdown during the COVID-19 pandemic. It is important to note that it has since become the trend even after the pandemic in most schools. Today, universities, other institutions of higher learning, secondary, primary, nursery and pre-Kindergarten schools and government agencies are investing in e-learning software solutions. Acceptance and adoption of ICT facilities among the populace has improved due to electronic methods of teaching and learning [2, 3] and this has enhanced the overall quality of teaching and learning.

This has also brought about a rapid increase in the number of available e-solutions for trainers and learners. E-solutions can be used outside conventional learning environments in distance learning, remote learning, personalized learning etc. and its many uses have led to a revolution of the education sector. Some of the tools that boost educational capabilities include the following modes of e-learning delivery; Distance Learning software systems, Learning Management System (LMS), Video conferencing apps (e.g. zoom and google meet) for teacher-student interaction and collaboration, real-time project co-editing, calendar scheduling, and auto-translation apps.

Studies continue to show a steady increase in demand for more suitable software solutions for learning despite the high number of available online learning tools in the market today, because the ones available have not adequately addressed the problem of usability in existing teaching or learning software solutions and in some cases both. This lack of user satisfaction with the e-learning solutions they have used or are currently using remains a recurring issue [4, 5]. The primary purpose of any e-learning solution is to aid learning, it is therefore expected that a software application developed for learning purposes must be enjoyable to use by both the trainers and learners for optimal utilization [6, 7]. Users should have a good experience with e-learning solutions for them to accept to and use it for its intended purpose. This is possible with customized e-learning solutions based on the peculiarities of trainers and learners so it is usable and give users satisfaction always. Developers of e-learning solutions should identify and understand the individuals (age, level of education, level of competency etc) to use the solution to achieve a successful customization. Some other factors that are necessary for consideration while developing the e-learning solution include the environment where the software is to be used and the ICT resources available for deployment of the developed solution.

1.1 Definitions of e-learning

The term e-learning can be described as synonymous to online learning, web-based training, internet based learning, distributed learning and net-based learning, and has been defined as a:

- Network or online learning that takes place in a formal context and uses a range of multimedia technologies. It is a learning system that is supported by electronic hardware and software either online (synchronous) or offline (asynchronous) [8].
- Multimedia based instruction, delivered using various instructional methods, which can be accessed by learners through their computers at their own will [9].

Electronic learning or e-learning is used by teachers, trainers or instructors to provide instructional programs for students at different locations. This form of learning is made possible by the availability of internet technology, tools like computers, laptops or smartphones, multimedia technologies and networks. It makes the following and more possible for both teachers and learners.

- Self-study by learners at any time and location
- Teachers are able to interact with and teach students outside conventional class environments

- Different skills can be acquired in various fields of study
- Customized and self-paced learning
- Communication with experts across the world virtually
- Accommodates more number of students for a lecture/class at the same time than is possible in physical classrooms
- Acquisition of world class education through access to lecture notes and tutorials on different topics from various international institutions
- Lectures can be recorded for future reference and replayed for recall.

1.2 Implementation of E-learning

1.2.1 E-learning pre-COVID-19 pandemic

E-learning was gradually gaining grounds before the pandemic as a necessity but there was no pressure to adopt this technology by institutions in the country. Most institutions adopting it were those of children and wards of elites. Institutions were encouraged to use it because of the associated gains but most schools could not due to the demands of technological advancements [10–12].

1.2.2 E-learning during e-COVID-19 pandemic

This period witnessed the implementation of several strategies to bridge the digital-divide in e-learning approach to teaching and learning [13]. Most institutions resorted to online classes for their academic programs while students used their devices to connect to online classes and listened to recorded teachings offline. Despite the economic hardship which became more severe during the pandemic, many parents/guardians of students who were willing to continue learning had no option but to procure computers, tablets, laptops and phones for their wards to join in the online classes and continue learning [14]. This crisis brought to the fore many areas of deficiencies and inequalities in education systems among which are lack of internet access and availability of devices for e-learning [15, 16].

1.2.3 E-learning post e-COVID-19 pandemic

After the pandemic, e-learning continued to gain ground and its implementation became more common at all levels of learning. However, due to poor maintenance culture and struggles involved in the acquisition of more recent facilities the use of e-learning systems has started dwindling and many institutions are adopting a mixed or blended learning system. There is a need to continue to emphasize the huge benefits that accrue from e-learning methods [10].

1.3 Why e-solutions in learning?

Many e-solutions exist for use in learning at different levels. The primary purpose of creating the various applications includes the following:

- to enhance learning
- customize learning
- make learning outside conventional environment possible
- give a wider coverage and provide alternatives sources of learning
- deliver learning solutions to learners doorstep

make teaching schedules more flexible and convenient for trainers

However, most software products still have limited usability as experienced in different scenarios when users have usability problem. When users encounter problems with software systems like e-learning systems, the following are likely to occur. They

- make mistakes at particular points or spots which is an indication that they do not understand that particular feature in the system
- take long time to complete a tasks and there seem to be no obvious improvements after a period of using the system
- need assistance to accomplish tasks with the system
- are reluctant to use the software

1.4 Challenges associated with using e-learning solutions

There are obvious challenges to the growth of e-learning technology in Nigeria [17]. Some of these include:

1.4.1 Lack of steady power supply

The epileptic nature of power supply in Nigeria is a hindrance to implementation of e-learning. Many parts of the country still struggle to have steady power supply and have to rely on secondary or alternative sources of power generation [18].

1.4.2 Poor economic status

The poor economic situation puts other sources of generating electricity out of the reach of many persons and institutions. A significant population of the nation live below poverty level which makes it difficult for them to the needs of their children and wards for optimal utilization of e-learning opportunities [19].

1.4.3 Lack of ICT infrastructure

The disparity in the availability of ICT facilities in some areas of the country especially rural areas continues to pose a great threat to the development of e-learning. Only a small percentage of the population in rural areas have access to computer and electronic devices for online learning [20–22].

1.4.4 Poor broadband penetration

Internet connectivity is required for e-learning activities among teachers and students [23, 24]. There is also limited bandwidth and challenges with internet connection making it difficult for learners to access online lectures real time and download materials like videos and lectures easily.

1.4.5 Training on how to use computer

Training teachers and learners on the use of different learning devices is not as well organized as it should due to limited access to devices. Many learners especially in primary and secondary schools use their parents' or older relatives, friends or neighbors phones for learning. It is evident that learners need more exposure to these devices to enhance their skills. Making it available and within reach will help train them more often and make them comfortable learning with them [25].

1.4.6 Lack of provision for learners with special needs

Students with special needs, disadvantaged backgrounds like states that have been victims of terrorists' attacks or those with Internally Displaced Persons (IDPs) have challenge utilizing e-learning technology. Some learners need special attention while learning and this lack of personal attention to these categories of persons make them unable to benefit much from the regular online learning [26, 27].

1.4.7 Lack of regular update training for teachers

Some teachers are not as knowledgeable in computer use as is required for online teaching, so they need further training. There is a need to conduct update courses for teachers to improve their skills and competency because students are adversely affected when the teachers lack the necessary skill for online teaching. Teachers who are involved in online teaching should not only have the know-how but enjoy using technology tools for students to be positively impacted by e-learning technology [28, 29].

1.4.8 Low computer literacy level among parents

Some children born in this computer age have parents that are not literate and some that are literate are not proficient enough in computer use to guide their children/wards on learning with computer. In most cases the students or learners are the ones who have to put these older ones through whenever they have difficulties working on their computers and devices. This makes it difficult for them to seek assistance when they encounter challenges using the device or the e-learning solution at home [30].

2. Usability of e-learning solutions

According to [31] usability often refers to how well users can use the functionality of the system. The ISO/IEC 25010 standard [32] defines usability as "the degree to which a product or system can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." It is a

software quality which includes the attributes of efficiency, effectiveness and user satisfaction. These three play a vital role in the evaluation of any software, including its usage, acceptance and sustainability.

Users' experiences with various e-learning solutions vary based on how these attributes have been built into the development of the software. Underestimating the importance of any of these attributes leads to a usability problem and an undesirable outcome like dumping the software solution, project failure, reduced productivity and crisis in organizations and poor learning experience [33]. User acceptance leads to a willingness to use a software solution to perform tasks for which it was developed and this helps improve productivity. Basically, usability depends on keeping users needs as a central focus in the design process (User Centered Design).

Gould et al. [34] highlighted four key principles of user-centered design. These include:

- Focusing early on users.

Identifying and understanding users' needs must be at the center of any successful software development project from the onset of the design process.

- Integrated design.

All phases of the design should be developed in parallel, instead of in sequence. The internal design of the product should be aligned with what is required for the user interface.

- Early and frequent testing.

The only currently possible method of software design is an empirical one. Integrating usability testing all through the development process gives users the opportunity to give feedback on designs before the release of the product.

- Iterative design.

It is necessary that designers and developers revise the design iteratively through rounds of testing. Iterative user-centered design (UCD) process can be applied to achieve good usability and User Experience (UX). The best-known UCD process is described in the ISO 9241-210 standard [35]. From the definition above, it is necessary to do the following in order to measure usability:

- identify a subset of the known group of users and involve them in the development project
- study the selected participants' situation and the problem they want to solve with the software product.

User Experience (UX) evaluations are vital for good usability, user studies and interaction design. The evaluations help to determine users need and the difficulties they encounter when using a system. Several evaluation methods exist for obtaining users' feedback to improve usability. Some of these methods are based on evaluation by UX experts and the commonest is usability testing with users, i.e. the actual end users perform typical tasks with the finished software product or a prototype.

Conventional methods can also be used in form of continual dialog between users and designers, where users are involved in the design process for example collaborative design workshops can be organized where users are allowed to formulate their own concepts/ideas or use scenarios.

It must be emphasized that developers are not typical users. They (developers) may be more knowledgeable in the technical aspect of the software development process but since they are not the actual users of the software product they must not assume that they know what the users want without robust interaction with them [36]. Software developers should empathize with the average user during the development of the software solution. Involving users early during software development improves interaction between developers and users and also fosters understanding among them while encouraging cooperation and ownership. It also gives the user a voice, thereby making them more willing to assist in the development process.

2.1 Attributes of usability

The definition of usability The ISO/IEC 25010 [32] listed three attributes of usability as effectiveness, efficiency and user satisfaction. The ISO 9241-11 standard [37] explains that this usability trio should be based on the context of use. These three and other identified components of usability are discussed below.

2.1.1 Effectiveness

The effectiveness of any software shows the usefulness of the software and the extent to which it solves users' problems. It can be measured as a percentage of the task completion with the software [33].

2.1.2 Efficiency

Efficiency addresses how a software solution solves identified problems and the ease of use of the application. In software engineering, it involves ensuring that the job gets done with less effort and not more than expected resources. Two metrics that can be used to measure efficiency are speed and interactivity, which shows the time taken by a user to complete a task and the number of clicks required to perform an activity [38].

2.1.3 User satisfaction

A software solution that does not solve users problem to their satisfaction is considered a failure. If it solves the problem but it is difficult to use or the user experience is poor then the usability of that software is adversely affected and user satisfaction will not be achieved. Satisfaction with a system is a measure of how pleasing it is to use. The style of the design must meet the needs and expectations of the users. Subjective satisfaction can be evaluated through UX questionnaires [39].

2.1.4 Engaging

The interface of any online learning application should be engaging and exciting to use. The visual design and choice of colors are things that easily attract users attention and influence their preferences (especially on web sites) in a software solution [40].

2.1.5 Error tolerance

An error tolerant program is designed to prevent errors that occur from the user's interaction with the system [41] and to help the user recover from errors when they occur. An error tolerant system must be forgiving thereby allowing users to undo actions executed but not deemed necessary again or performed in error-back tracking.

Nielsen's usability definition however divides usability into five elements (attributes) which can be measured and used to specify usability objectives. They include efficiency, memorability, learnability, errors and satisfaction (**Figure 1**).

2.1.5.1 Learnability

Software systems should be easy to learn if users must have a good first impression of a system. Any experience contrary to this expectation will make users reluctant to return to the system. Not only experienced but novice users as well must be considered when designing to give users good experiences from a software system [42, 43].

2.1.5.2 Efficiency

Some users do not need to learn to use a system fully, they are satisfied by just learning its basic functionalities. Simplicity in interaction and visual design can make a user interface (UI) more efficient [44].

2.1.5.3 Memorability

Memorability measures how well users remember the different functions in a system after they have learned them. Sometimes even when the system has not been in use for some time, it is still possible to remember the functions when a system is designed with memorability in mind [43].

Simplicity and clarity reduces the number of possible errors users make while using a system. When a system is well understood, possibility of errors occurring is reduced. Errors are functions performed by a user which does not lead to the desired

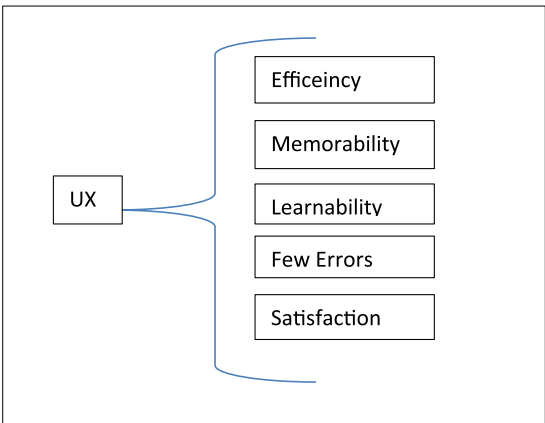


Figure 1.
Jacob Nielsen's usability attributes.

results. Error frequency of a system contributes significantly to the measurement of the effectiveness of that system [43].

2.2 User experience

Usability is a key aspect of the UX [45]. The concept of UX is currently gaining more ground in the software industry. It covers the totality of users impression about a software application, all aspects of user interaction, from their sensations, emotions and affects to the characteristics of the developed system and the environment where the interaction takes place [46] and opinions, trends, brand/image and social value [47]. Hence, the involvement of end users is imperative to achieve success in UX design process.

According to ISO standard (9241-210) [35], UX is “a person’s perceptions and responses that result from the use or anticipated use of a product, system or service”. There are various important tools which can be used to explain the concept of UX design to users. One of these resources is the user experience honeycomb by Peter Morville, a designer and information architect. He started with a diagram of three circles which he used to represent the link between (1) user needs and behavior (2) business goals and context and (3) content (**Figure 2**) [48].

Each application will be different based on the balance between context, content and users. Keeping all of these points in mind makes it easier to define priorities. This is also essential for helping companies break down tasks in order to formulate a strategy toward an end goal.

Consequently, it became necessary to come up with a better diagram that showed an in-depth explanation of user experience design, this led to the development of the user experience honeycomb. The user experience honeycomb is a tool which helps to explain the various facets of user experience design. A focus on the UX honeycomb will enable stakeholders identify the most important areas of user experience and begin the project by plugging away at the high level priorities, thus over time allowing the software solution to completely redefine the user experience remarkably.

Figure 3 shows seven items that comprise Peter Morville’s UX illustration of the facets of user experience design [48]. They include:

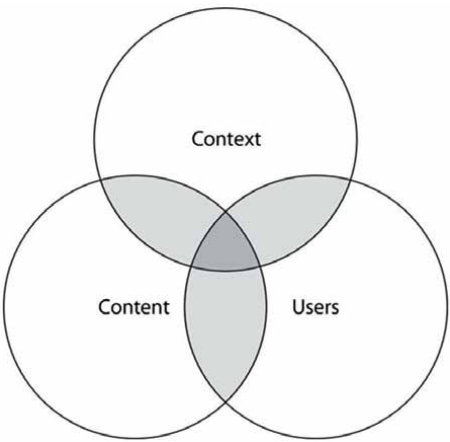


Figure 2.
Peter Morville concept of UX.

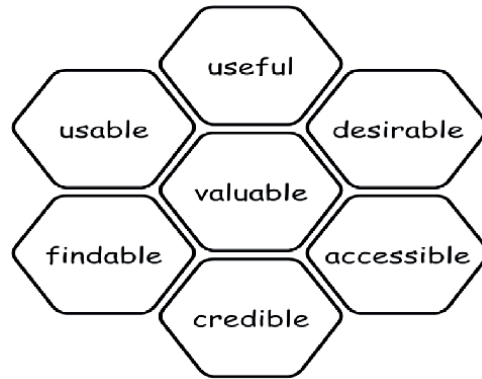


Figure 3.
Peter Morville's UX illustration of the facets of UX.

2.2.1 Usable

The system should be designed based on users' peculiarities in order for them to understand it and not be alienated from the system. It should also be simple and convenient to use. Target users should be the central focus throughout the design process so the system will be suitable for use and address their needs.

2.2.2 Useful

The system should be designed to address users' problems instead of wasting their time, as this is the only way the software system will be useful to them.

2.2.3 Desirable

The visual esthetics of the system should be attractive to users and easy to translate. Design should be straight forward and appealing to the users for whom it was developed. This will make them to be willing to use the software application regularly.

2.2.4 Findable

Information should be easy to locate and there should be no difficulties navigating the interface. It should be possible to resolve users' problem easily and quickly. User Interface (UI) should not task software users to think beyond the problems they want to solve with the system to be bothered with technicalities of the design.

2.2.5 Accessible

The system should be designed for all categories of users to have the same user experience as others. A situation where experienced and novice users have different user experience with a system makes the system not accessible to all.

2.2.6 Credible

The system should work as the developer agreed with the users. This will make the users to have a good first impression and trust in the software product.

In refs. [11, 49] characterized the standards related to usability as follows:

1. The use of the product (effectiveness, efficiency and satisfaction)
2. The user interface and interaction.
3. The process of developing the product.
4. The ability of an organization to apply user-centered design.

3. Challenges of usability in e-learning solutions

Despite the numerous e-learning applications in use today, there is still demand for innovative software solutions for online teaching and learning. Some of the reasons for the dissatisfaction by users are:

3.1 Diverse learning needs

Different learners have varying learning styles and preferences hence different expectations from e-learning systems, which the existing systems have not adequately catered for in the available systems [50].

3.2 Technological advancements

Trainers and learners expect e-learning systems to incorporate functionalities and features of emerging technologies to e-learning systems to improve learning outcome. Some of these latest technologies are Virtual Reality, Artificial Intelligence and Gamification [51].

3.3 User experience and engagement

To provide an engaging and intuitive user experience should be the focus of any successful e-learning system development. Users should enjoy their learning experience and this is the way to fulfill this desire of users [52, 53]. Many e-learning systems are short-lived and lead to waste of money and effort because they do not meet usability standards.

3.4 Learning efficiency

A well designed e-learning solution should provide simple and straightforward pathways for efficient interaction. The UI should not be cluttered or busy as this will increase learners cognitive load [54].

3.5 Accessibility and inclusiveness

E-learning systems should be accessible to all categories of users including those with special needs. Involving them in the development or acquisition of the software solution will help ensure usability [55].

4. The way forward

Adopting innovative pedagogies is non-negotiable for online education delivery to have the desired reaching effect on both teachers and learners and boost productivity in any institution. Finding solutions by focusing on pedagogical issues and laying greater emphasis on case learning, collaborative learning and project-based online instructions can go a long way. However, Governments must put in the requisite effort necessary to reduce the gap in online education delivery by addressing the identified and obvious challenges in the face of economic inequalities.

Reimagining Education is a clarion call for stakeholders in education sector and Information Technology (IT) experts. E-learning has redefined teaching and learning and has proven to be more beneficial when usability is considered in the development of software solutions for online teaching and learning activities. To ensure usability of an e-learning solution, the following are suggested. It should

1. Personalize capabilities based on profiling of users of the system
2. Have an intuitive interface
3. Have a concise documentation of the system platform
4. Be easily accessible from any device.

E-learning solutions should be built to suit different users based on their preferences. User studies is therefore recommended to enable good teaching experience and learning journey.

5. Conclusion

Use of digital learning solutions in learning and teaching is commonplace in the Education sector today and there is a wide variety of digital learning solutions. Usability is a key element in successful software development project. When the actual users of a software product are not known, understood and involved in the development of the solution, the development project will result in failure. Ensuring the technical usability of a learning solution enables users to focus on their main task, learning. It is advisable to ensure a level of technical usability for devices and software used for educational purposes. There should be a basic level of technical usability so that learners can focus on learning rather than encountering problems from the technology.

The role of e-learning, creativity and technology cannot be over-emphasized in the development of successful and sustainable online solutions for teaching and learning in today's post pandemic era. Creativity is critical for the design of a software system that will be usable and useful to teachers and students. Interacting with and understanding target users of a software product during requirements gathering and subsequent phases help in idea generation for enjoyable products. Usability is achieved when necessary consideration is given to these issues and this will lead to the desired improvement in e-learning technology and increase in its uptake.

Abbreviations

ICT	Information and Communication Technology
LMS	Learning Management System
UCD	User Centered Design
UX	User Experience
IT	Information Technology

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E-Learning Success: Requirements, Opportunities, and Challenges

Ismail M. Romi

Abstract

A lot of models and frameworks were suggested to conceptualize and operationalize the e-learning success, and enhance the e-learning and learner performance. Most of these model tries to find out the optimal match among the e-learning components in order to enhance e-learning and learner performance. This chapter explores the e-learning system, its components, e-learning success requirements, opportunities, and challenges that may enable or inhibit e-learning success. As a result, the best fit among the e-learning system components (instructor, learner, course, ICT) is to choose the best mix of the components' characteristics, as well as taking into consideration the contextual factors (individual, institutional, and environmental) that have a direct impact on the e-learning system components and hence impacts the learner performance. On the other side, institutions must take into consideration the e-learning developments, which take two main directions, mainly; technological, and mechanisms developments. As well as the e-learning challenges which can be classified into technological, individual, institutional, environmental, and educational challenges. To cope with these developments and challenges, an adaptation plan must be formulated at the national level. Where achieving the adaptation plan requires analyzing the global tendencies, the successful applications in the field, and the current local situation.

Keywords: E-learning, E-learning success, E-learning requirements, E-learning opportunities, E-learning models

1. Introduction

The COVID-19 pandemic has dramatically changed education. Where sudden and rapid shift occurs from face-to-face classrooms into forms of e-learning and distance learning [1]. This shift in education accelerates the efforts to handle the new sudden trend in e-learning in both the market and research.

The market of e-learning continues it's growing in an accelerated manner. It's highlighted that due to COVID-19, 62% of businesses are affected by changes, and spending more on training in 2021 [2]. As well as the educational institutions which are turning to eLearning tools to provide continuing education to students remotely via the Internet [3]. Tamm (2020) shows that by 2022, the global e-learning industry is projected to surpass \$243 billion, in addition to the eLearning industry growth which is projected to increase to \$370 billion by 2026 [3, 4].

Its highlighted that the rise of e-learning tools has revolutionized the higher education sector, boosting improvements across fields of knowledge and information. Where 85% of learners who have experienced both virtual and in-person classrooms feel that online learning is better or as good as the traditional classroom setting, 67% of educational institutions are in the planning stage of deploying learning management system (LMS) platforms [3].

A lot of models and frameworks were suggested to conceptualize and operationalize e-learning success and enhance e-learning and learner performance. Most of these model tries to find out the optimal match among the e-learning components in order to enhance e-learning and learner performance.

In an attempt to find out the optimal match among e-learning components, this chapter will present e-learning success requirements, opportunities, and challenges that may enable or inhibit e-learning success.

2. E-learning success requirements

Figure 1 depicts a model for e-learning system success [5]. The model was developed depending on prior researches and theories including; the information system success model (D&M) [6–8], technology acceptance model (TAM) [9], situational theory of publics (STP) [10], multilayer model of user activity [11–13], action theory [14], situated action theory [15], and GOMS model [12].

The main aspects of the model are the e-learning system, determinants of e-learning success, and learner performance. Where the learner performance depends on the e-learning system and the fit among its components, meanwhile the success of the e-learning systems is determined by the individual characteristics and the institutional and environmental contexts.

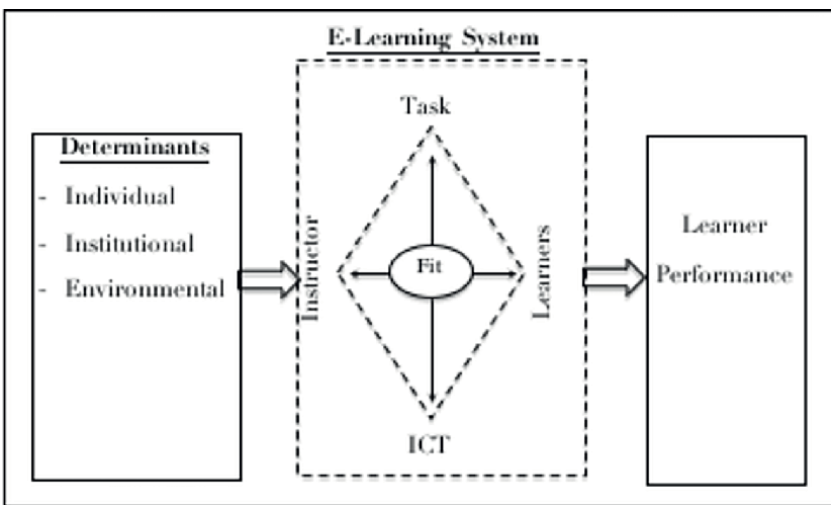


Figure 1.
A model for e-learning systems success. Source [5].

2.1 E-learning system

2.1.1 E-learning concept

A number of definitions were formulated for e-learning. Meanwhile, it's defined as the delivery of learning through information, communication, education, and online training [16]. It can be defined as integrating mechanisms and content of learning and Information Technologies [17, 18]. Furthermore, e-learning is a supported learning environment, where, it's accessible, well-designed, student-centered, inexpensive, efficient, and flexible [19, 20].

Therefore, e-learning can be defined as delivering the learning content via Information and Communication Technologies using systems and tools prepared for that.

2.1.2 E-learning system concept

E-learning system refers to using electronic applications and processes to learn via the Internet, network, or standalone computer, in order to enable the transfer of skills and knowledge [21]. Furthermore, an e-learning system as an information system that integrates human entities (i.e., learners and instructors) and non-human entities (e.g., learning management systems), it is crucial to investigate multiple dimensions of success in relation to both entities [22].

2.1.3 Components of E-learning system

It has been reported that an e-learning system consists of four main dimensions, mainly; learners, course (content) to be presented to learners, instructor (presenter) who is responsible for designing the course content and following up the learners' achievement, and the information & communication technology (ICT) which is used to mediate e-learning. Where, achieving high performance, requires a good fit among e-learning system components, where the higher fit between e-learning system components will lead to higher learner performance. This implies that each component of e-learning systems must possess set of characteristics in order to strengthen the fit [5].

2.1.3.1 Instructor (presenter)

It's reported that the instructor characteristics that enable the best fit among the e-learning systems components are enthusiasm, style of presentation, friendliness toward learners, a genuine interest in students, encouraging learner interaction, handling the e-learning units effectively, explaining how to use the e-learning components, keen on using the e-learning units, learners were invited to ask questions/ receive answers, encourage learners to participate in class, encourages and motivates learners to use e-learning, active in teaching the course subjects via e-learning, support, cautious when including e-learning as part of the assessment, timely response, self-efficacy, technology control, focus on interaction, attitude toward the learner, interaction fairness, computer self-efficacy, responsiveness, and instructor attitude toward e-learning [9, 23–31].

2.1.3.2 Learners

It's highlighted that the learner characteristics in the e-learning system are searching for facts, participating actively in discussions, using the PC and applications, not being intimidated by using the e-learning-based courses, learning by absorption, learning by construction, accessing diverse student population, interactive communication, all students have to participate in the discussions, students have to interact with each other both within and outside the online space, flexibility of time and hours, mandatory quizzes and exercises, computer self-efficacy, internet self-efficacy, attitude toward e-learning, students' support, collaboration, interaction, learner control, age, entrance scores, experience, language, learner preferences, locus control, motivation, expected workload, previous e-learning experience, training, engagement, awareness of utilizing E-learning systems, student Online learning activities, student autonomy, and students background [23, 24, 31–40].

2.1.3.3 Course (content)

Course characteristics can be defined as the clear instructions, sufficient course content, the structure of e-learning components, navigation, e-learning components were available all the time, the course materials were placed on-line in a timely manner, good design of the e-learning components, course quality, relevant content, course flexibility, development of courses, course structure, suitability of course content, course flexibility, active Learning, applicable to practice, balance between asynchronous and synchronous activities, cognitive load, design, instructional scaffolding, modeling, problem-based learning, and practice, structure course development technologies, models of courses and their pedagogical design, availability of the course curriculum, course delivery technology, ease of access to courses and services, convenience of course navigation, availability of guidelines for working with course materials, availability of interaction technologies, and adaptability and personalization of the course [24, 28–33, 40].

2.1.3.4 Information and communication technology (ICT)

To achieve the best fit, ICT must be easy on-campus access to the Internet, satisfying speed, easy to use, information was well structured/presented, pleasant, Interaction, easily contact the instructor, can use any PC at the university, can use the computer labs, reliable, can use banner, efficient information technology infrastructure, user-friendly platform, computer playfulness, usability [24, 31, 33, 35].

To achieve the best fit among the e-learning systems components, the Situational Theory of Publics [10] show that classifying learners into different groups based on their level of awareness about the task, and the extent to which they do the task will enhance the fit between the learner and the task. On the other hand, the learner must have technical skills and knowledge to navigate online learning in order to achieve a fit between the learner and technology. Where, the Multilayer Model of User Activity [11–14] adds that achieving fit between the human (instructor and learner), the computer (ITC), and the task occurs through four levels of interaction. Where each level provides the context for the level below it starting from the task level until reaching the lexical level; which is closest to the resources that are needed to physically implement this task. Meanwhile, the GOMS model [12] enables predicting the required

time for completing the task and urges to use the best interface, which achieves the best performance for the user.

2.2 Determinants of E-learning system

It's highlighted that the determinants of an e-learning system can be divided into three main dimensions, mainly, individual, institutional, and environmental determinants [5].

2.2.1 Individual dimension

Refers to the individual learner's perception of the impact of using an e-learning platform in terms of her/his learning performance [6]. Where individualism and collectivism; which is the degree to which students' social behavior is driven by personal rather than collective goals, is an important determinant of e-learning success [41]. Furthermore, it's highlighted that learners perceived collaboration quality and interaction with others, and user satisfaction appears to be an important success factor in e-learning systems [42].

2.2.2 Institutional dimension

Refers to the support from the institution; which may include supporting department, library service and help desk service. It has been reported that institutional support has a strong impact on e-learning systems' success [31, 43].

The support aspects that have an influence on e-learning systems are culture, recognition of work, providing training, reward systems, organizational learning culture, management support, institutional policy, information security policy, teaching and learning strategies and policies, computer training, clear direction, technical support, technological infrastructure technical resources availability, and time availability to learn [23, 24, 32–34, 44].

Furthermore, it has been reported that the learning management system which includes application and integration, communication, assessment, content, cost, and security has a significant impact on e-learning success [45].

2.2.3 Environmental dimension

It has been reported that environmental factors have an impact on e-learning success. These factors include social influence, learners' perceived interactions with others, subjective norms, student consensus, group and peer interaction, authority, and faculty and societal pressure [24, 46, 47].

2.3 Learner performance

2.3.1 Performance concept

It's highlighted [48] that performance is referred to as the result of a pattern of action carried out to satisfy an objective, according to some standards, where performance-related goals are improving the human ability to handle the physical load or demands of the work situation. Therefore, performance can be measured by reducing errors, improving quality, reducing the time required to complete tasks, and end-user

acceptance of the system [48]. The educational outcomes include satisfaction, knowledge, attendance, adherence, and self-reported change in practice [33, 49].

2.3.2 E-learning and learner performance

It's reported that e-learning enables the learner to gain more freedom in the e-learning process, where, the learner can acquire and transfer knowledge, enhanced communication among learners, the ability to conduct an open discussion, each learner gets more of equal standing, responses can be made around the clock with no restrictions, higher motivation, and involvement in the process on the part of the learners, the study is based on various sources of information; including online data banks and net experts located by the student, the student learns “how” and less “what” [5, 50]. Furthermore, the content can be easier and faster to modify and update [51]. Meanwhile, online learning produces collaborative learners who can learn in groups [52].

2.3.3 Achieving the best learner performance

Figure 1 shows that learner performance is determined by the e-learning system components fit (instructor, learner, task, ICT), where the higher fit will lead to higher learner performance. As well as, taking into consideration the contextual factor (individual, institutional, environmental) that affects the degree of fit among e-learning components.

Figure 2 depicts the e-learning components fit as the match among the computer design (ICT) and the user (instructor, learner) and task [5]. It's reported that achieving the best fit can be achieved by task analysis, reducing user efforts, training the user well, and using suitable interface objects and colors [48]. ISO 9241 standard highlights the interaction goals as effectiveness, efficiency, and satisfaction [53].

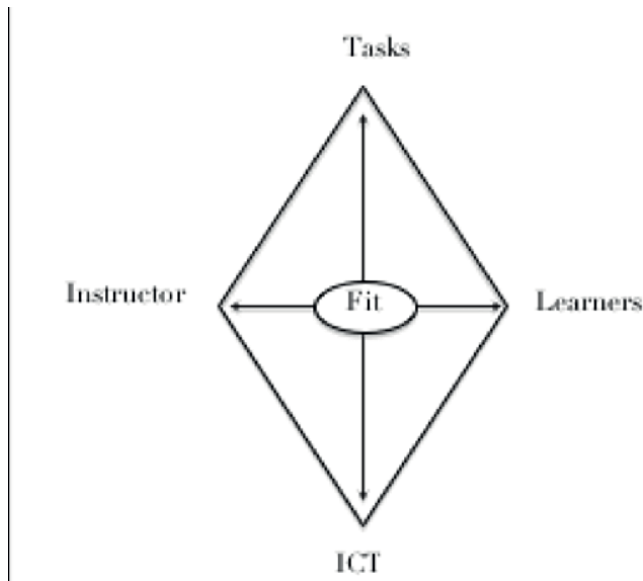


Figure 2.
The interrelationship among E-learning components. Source: [5].

Where effectiveness is the accuracy and completeness with which specified users can achieve specified goals in particular environments. Efficiency is achieving goals with minimal resources. Satisfaction is the acceptance and comfort by users of the system.

3. E-learning opportunities

The development of e-learning takes two main directions, mainly; technological, and mechanisms developments.

3.1 Technological developments

Building a more inclusive e-learning environment involves making technological choices built on flexibility and an ability to respond quickly to changes in constantly evolving technology and informational resources [54]. It's reported that deploying and managing e-learning systems require huge investments in IT and many educational institutions cannot. Where, cloud computing is envisioned to be the next-generation architecture of the IT industry, and promotes the delivery of powerful computing resources as a service. Therefore, there is a potential value for cloud computing as a platform for e-learning. It's highlighted that cloud computing promotes on-demand self-service, enables applications to be accessed through heterogeneous platforms, location-independent pooling of computing facilities for serving multiple, and enables scalability of services provided [55]. In addition, the adoption of cloud computing provides flexibility in storage, sharing, and access for both learners and content providers. As well as using new tools mainly; virtual reality (VR), augmented reality (AR), and social networks that allow introducing new elements in the learning process. Furthermore, mobile learning which enables the use of mobile technologies in the learning process [56].

3.2 Mechanisms developments

The development of e-learning is rapidly expanding. Where, e-learning has become one of the most important and potentially significant, and efficient instructional methods to improve teaching, learning, and assessment [57]. As well as improving time management skills, technical and communication skills, and gamification skills, enabling searching any study material, and enabling instructors to use lots of study material [58].

These developments and changes made higher education replace virtual universities and cross-border education with e-learning [54]. In addition, open communication and management approaches will become the driving techniques to enhance learning skills in virtual environments, which will meet the new requirements of societies [54]. Furthermore, the recent trends in the assessment of students' academic performance at the university level demand a new approach to assessment using e-learning in which assessment plays an integral part in instructional activities. Where the results showed that e-assessment would yield objective results with great reliability [57].

It's reported that the higher education system, a skill-oriented professional discipline requires adequate skill development among the learners, which changes over time depending upon the development of methods and techniques of the concerned professional discipline and the requirement of professional competency

in the marketplace. Furthermore, IT development for access and utilization of information is dramatically changing the role of teaching from the custodian role of teaching to the role of facilitator and distributor. Furthermore, the purpose of higher education is to provide skills for developing professionals who link people and information, where, the basic skills required are the intellectual organization of information and processing, management, retrieval, and provision of information to its students [59].

These developments and changes require developing mechanisms that strengthen the e-learning process. Those mechanisms include; asynchronous and synchronous learning; where, synchronous learning is a teaching method in which the learner and the instructor interact virtually at a particular time, meanwhile, asynchronous learning is a teaching method where the contact between the instructor and the learner is delayed. Another important mechanism is micro-learning which allows students to learn lessons in a short time. Furthermore, gamification enables using the game elements in the learning process. In addition to an individual approach where the psychological and intellectual abilities of the student are taken into account. As well as using new approaches to the assimilation and updating of knowledge [56]. As well as the availability of e-learning facilities will help to get the best out of the instructors. As well as the delivery of the lecture materials will also be made easy, and learners will, at any point in time, have access to the materials [60].

To cope with the continuous developments and changes an adaptation plan must be formulated at the national level. It's highlighted that, making local adaptations to education management by following the new developments in education management that arise due to technology and social change. Achieving this adaptation requires analyzing global tendencies, the successful applications in the field, and the current local situation [61]. The developments must take into consideration all types of education; school education, the training market, the training services offered by consulting firms to companies, courses, and other skill-building training. These developments will be effective when it's formulated in the national development plans (National Educational Technology Plan) which embrace all society citizens and are included in the education policies and future strategies of the countries [61].

4. E-learning challenges

Implementing e-learning may face some challenges. These challenges can be classified into technological, individual, institutional, environmental, and educational challenges.

4.1 Technological challenges

It's highlighted that the connectivity, technological, and self-regulation issues are challenges that may face the e-learning systems [62, 63]. As well as, the enabling technologies including the used technologies for the e-learning systems, content management systems, and the proper infrastructure and bandwidth requirements needed [64]. In addition to the Technical failures on the Internet, and poor scalability of the software; such as technical failures during a live broadcast on any site (the quality of sound and video, a time lag between the instructor and the students [56].

Furthermore, e-learning challenges reported include inadequate Information and Communication Technology (ICT) infrastructure [65], and e-learning tools'

preferences that differ among nations [58]. In addition to the lack of IT proficiency [59], and technical difficulties in creating an e-course; which is the systematization of educational material and the development of an electronic space for its placement) [56].

4.2 Individual challenges

The reported challenges which are concerned the instructor, or learner when using an e-learning system may include the isolation of some learners and lack of social interaction, lack of direct contact with the instructor [54], and instructors may be challenged by competency, operational, self-regulation, and isolation issues [62]. Furthermore, the limited skills for the use of e-learning [63], lack of motivation [66], and negative perceptions toward e-Learning [65].

Another reported challenge is personalization; which is concerned with adapting the course content in such a manner that suits the different learners' styles, preferences, and needs. Where visual learners often prefer visual stimulants, auditory learners prefer auditory stimulants, and kinesthetic learners prefer tactile stimulants. As a result, personalization is crucial to help in maximizing and speeding up the learning process. Especially when learners deal with different technological devices [64].

4.3 Institutional challenges

The main challenges that may face institutions while implementing e-learning are lack of financial support where an e-learning system requires expensive hardware and software that requires a huge investment [59]. E-learning system support, change management [62], lack of knowledge, resources, and training [67]. Furthermore, challenges that may occur are existing organizational structures, inadequate e-learning policies [65, 67].

4.4 Environmental challenges

It's reported that political and religious challenges may be sensitive for the trainers, educators, and the country. Meanwhile, cultural challenges, where the traditional education culture methods and techniques and tools differ from e-learning technology methods and tools. In addition to, language challenges [58]. Furthermore, lack of collaboration among e-learning participants is reported as one of the important challenges for e-learning success [65].

4.5 Educational challenges

The highlighted educational challenges are differences in education systems, where, each country has its education system and policies [58]. As well as insufficient contact classes, and a lack of evaluation, where, there is no mechanism for assessing teaching effectiveness and quality of study materials of e-learning program courses [59] lack of guaranteed results [56]. Furthermore, different challenges may occur to instructors, and learners depending on the course methods (synchronous, asynchronous, blended, theoretical, lab-based, collaborative, and cooperative [54, 64]. While low quality of interaction, lack of class activities and forceful adoption of e-learning, limited student motivation, and limited engagement and satisfaction are reported as challenges to e-learning success [66, 67].

5. COVID-19 pandemic as a catalyst for future E-learning

As a result of the imposition of restrictions on mobility during the COVID-19 pandemic, educational institutions were forced to shift from face-to-face to online learning [68]. This pandemic is improbable to be the last. Therefore, interested institutions and governments should not lose sight of that [69]; they must consider the pandemic as a catalyst for the digital transformation of learning [70].

It's reported that there are negative attitudes toward e-learning acceptance during the lockdown situation and its effects on students' academic performance [69]. The reported reasons for these negative attitudes include some students who were found to experience internet problems, communication problems, and unfavorable live conditions. [68]. Furthermore, uploading amounts of material more and more times in a short time [70]. Besides time management capability problems and low quality of teaching [68]. In addition to the lack of practical work in the laboratory and communication with teachers or other students [71]. As well as, the influence on the character of students, where some students are getting nervous due to the necessity of always being on the internet [71].

These problems and challenges require interested institutions and governments to analyze their students' learning habits and preferences, as well as the internal and external challenges and problems, in order to make superior decisions that help in sustainable e-learning. The reported recommendations concerning these decisions include ensuring internet quality, ICT improvements, and accessibility as the most important factors that impact e-learning behavior [71]. Furthermore, it's proposed that the blended learning model, could adapt learners to new realities and resolve most of the problems while embracing all positive lessons from the pandemic lockdown [70, 71]. Where, implementing this model requires using e-learning as a complementary part of the education process [69], and sharing practical assignments with students on a predefined basis [70]. Additional recommendations were reported, mainly; providing additional classes on computer literacy [69, 70], providing dual training for both instructors and learners in the educational context [72], and pedagogical updates for teachers on how to use digital educational platforms and how to manage classes, discussions, evaluations, and communications with students [70], and ensuring the quality of the student's home environment [68].

6. Conclusion

E-learning can be defined as delivering the learning content via Information and Communication Technologies using systems and tools prepared for that. Where, a lot of models and frameworks were suggested to conceptualize and operationalize e-learning success, and enhance e-learning and learner performance.

The e-learning system consists of four main dimensions, mainly; learners, instructor, course (content), and information and communication technology (ICT). Where achieving high performance, requires a good fit among e-learning system components, where a higher fit between e-learning system components will lead to higher learner performance. Meanwhile, a good fit can be achieved by selecting the best mix for the e-learning system components' characteristics. Taking into consideration the contextual factors (individual, institutional, environmental) that affect the degree of fit among e-learning components.

E-learning developments take two main directions, mainly; technological, and mechanisms developments. Where building a more inclusive e-learning environment involves making technological choices built on flexibility and an ability to respond quickly to changes in constantly evolving technology and informational resources. Meanwhile, mechanisms developments are concerned with the e-learning product and methods that enable e-learning success. To cope with the continuous developments and changes an adaptation plan must be formulated at the national level. Where achieving the adaptation plan requires analyzing the global tendencies, the successful applications in the field, and the current local situation.

Implementing e-learning may face some challenges that hinder implementing successful e-learning. These challenges can be classified into technological, individual, institutional, environmental, and educational challenges. This implies that the institutions must plan well to overcome these challenges.

As a result of the negative attitudes toward e-learning acceptance during the lockdown situation; interested institutions and governments must consider the COVID-19 pandemic as a catalyst for the digital transformation of learning. They have to analyze students' learning habits and preferences, as well as the internal and external challenges and problems, in order to make superior decisions that help in achieving sustainable e-learning; such as ensuring the infrastructure quality, using the blended learning model, and providing dual training for both instructors and learners in the educational context.

Acronyms and abbreviations


AR	Augmented reality
D&M	Information system success model
GOMS	Goals, Operators, Methods, and Selection
ICT	Information and communication technology
ISO	International Organization for Standardization
LMS	learning management system
STP	Situational theory of publics
TAM	Technology acceptance model
VR	Virtual reality

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Discovery Space: A Technology-Enhanced Classroom for Deeper Learning in STEM

Sofoklis Alexander Sotiriou and Franz X. Bogner

Abstract

Traditional assessments of cognitive skills (in general) and knowledge acquisition (in specific) are in place in most educational systems. Though not in line with innovative and multidisciplinary curricula as proposed by current reforms, they require in-depth understanding and authentic application. This divergence must be addressed if STEM education is to become a fulfilling learning experience and an essential part of the core education paradigm everywhere. An alternative approach for assessment offers Artificial Intelligence (AI) tools designed to continuously monitor the individual progress, provide targeted feedback, and assess the student's mastery. All this information might be collated throughout a student's time in formal (and in some cases in informal or non-formal) educational settings. While the use of AI-driven continuous assessment offers a replacement of high-stakes stop-and-test examinations, its application needs to take into consideration its benefits and challenges. These applications (AI-enabled adaptive and continuous assessment) have been heralded as constituting a "fourth education revolution." However, concerns include challenges regarding their effective integration into educational practice, the lack of robust evidence for their efficacy and potential impact on teachers' roles. In this chapter, we present our vision based on long-lasting experience in employing ICT-based innovations in education. Our roadmap for the AI-enhanced classroom for deeper learning in STEM is supposed to facilitate the transformation of the traditional classroom to an environment to promote scientific exploration and support the development of key skills for all students. We describe the findings from a large-scale foresight research exercise that increases the understanding of the potential, opportunities, barriers, and risks of using emerging technologies (AI-enabled assessment systems combined with AR/VR interfaces) for STEM teaching. Our approach builds upon the extended use of an Exploratory Learning Environment that has been designed to facilitate students' inquiry and problem-solving while they are working with virtual and remote labs. By enabling this platform with AI-driven lifelong learning companions to provide support and guidance we intend to enhance learning experiences, facilitate collaboration, and support problem-solving. The provision of elaborated Good Practice Scenarios may adjust options for learners of quite different achievement levels and equip them with the skills necessary for the use of technology in creative, critical, and inclusive ways.

Keywords: artificial intelligence, deeper learning, AI-enabled learning companion, STEM-education, smart science classroom, alternative assessment methods

1. Introduction

The recent lockdown has thrust us into a period of fast-moving digital reforms in education, which requires us to respond accordingly. We need to empower teachers to make the most of digital advances and provide various digital learning solutions while we learn to understand how technology can foster deeper learning. This entails reconsidering student learning, how technology can support it, and how to combine their expertise as a profession. In turning the promises of education technology into reality, students were one of the most vulnerable groups to the coronavirus school lockdown times imposed by policy authorities. The crisis had relentlessly disclosed inadequacies and inequities in our education systems – not only the lack of broadband and computers needed for online education but also additional support for learning environments enabling a focus on learning. While the crisis had amplified inequities, it also offered opportunities to not return to the status quo when things return to “normal.” When authorities closed down schools in early 2020 to deal with the COVID-19 pandemic, learning suddenly had to go online. For teachers, students, and administrators, this change initiated a collective pile-up of courses on digital education – often without any previous planning [1]. All of us know about the avalanche of downsides, starting from screen fatigue and adaptation stress until the individual failure to deal with digital learning or the students’ unpreparedness to learn on their own. However, the unexpected experience urged education systems for rapid changes, without chance of slowcoaches to gradually prepare for innovation and steward for smart schooling [2].

Within the described circumstances, remote classrooms were not smart ones. This was especially true, as it had to act as a stop-gap measure to keep learning going and conserve existing educational practices rather than act as a transformation agent. In consequence, remote classrooms rarely were able to substitute physical ones. Although major syllabus deficits apparently were avoided, online classes could bridge neither technologically nor mentally the sudden gap. An example are science classrooms and labs [3]. In most EU countries, experimental hands-on work, inquiry-based activities, and problem-solving tasks have not found their digital twins during the schools’ closure. Even in hybrid schemes of delivery of education services, the restrictions posed created a rather problematic framework for the implementation of inquiry-based projects and activities. At the same time, the introduction of inquiry-based approaches into school curricula remains a major priority in Europe [4]. Most authors regard inquiry as the appropriate catalyst to clear the ground for students’ deeper learning competence (academic knowledge, problem-solving skills, cooperation and creativity, and/or development of academic mindset) [5]. It has great potential for supporting the academic success of students, bridging gender gaps, and producing a well-qualified workforce with optimally adopted Science Technology Engineering, and Mathematics (STEM) skills [6, 7]. Research in science education provides clear evidence that learning in an active way is regarded as a necessary condition for acquiring deep knowledge and skills [5, 8–10]. Inquiry learning (often based on hands-on experiments) may easily allow students to make active choices (choosing the next step in performing an action, for instance by changing a variable), experience the consequences of their own actions, and adapt individual knowledge and skills in response to an experimental set. Beyond remote learning, the assessment of the development of those competencies consists of a major challenge for educational systems [7, 4].

There is a major mismatch between opportunity and action in most education systems today. One of the most consequential mistakes of classroom education originates in the divorce of the learning process from assessment; that is, having students pile up

lots of learning and then, testing whether they could reproduce some narrow slices of that learning within a short time slot. Although the validity, reliability, or accuracy of high-stakes examinations are heavily disputed, almost all educational systems around the world are building upon them. This basic trust on examinations in place imposes schools and universities often teach just for the test, prioritizing routine cognitive skills and knowledge acquisition by neglecting in-depth understanding, and authentic application. These approaches, however, are not harmonized with the innovative and multidisciplinary curricula proposed by current reforms focusing on the development of twenty first-century skills, mainly in STEM education [11, 12]. Educational systems are still adopting traditional assessment methodologies that cannot monitor the development of students' competencies while working on specific tasks and experiments, making hypotheses, creating models, solving complex problems, reflecting on everyday phenomena and situations, and learning how to think scientifically [13]. This divergence must be addressed if STEM education is to become a fulfilling learning experience and an essential part of the core education paradigm everywhere [14, 15].

What can technology do for smart classrooms? First of all, a reintegration of learning and assessment would help as well as options to use real-time data and provide feedback to help students learn better, but also teachers teach better and more effectively [16]. While kids are studying science on a computer, the AI system can shadow how we study and in this way make our learning experience more adaptive and interactive. In line with sensors and appropriate management systems, AI can feed back how students learn differently, in which topics they are interested or distracted, and where and when they advance or get stuck [17, 18]. Technology can help to adapt learning to various student needs and give learners greater ownership over what they learn, how they learn, where they learn, and when they learn. AI has already invaded educational contexts in multiple ways by using cutting-edge technologies: Nevertheless, those applications often do not have more than the programmed lessons of the 1970ies which automate some outmoded classroom practices. AI can offer more sophisticated channels by using unique affordances to reimagine teaching drastically. In other words, the attention of AI developers so far has focused on the relatively easy-to-address tasks such as memorizing and recalling knowledge [19]. Address more complex educational issues, such as collaborative learning options or new ways to assess and accredit, would offer quite other paths.

An alternative approach to assess twenty first-century competencies might originate in AI tools designed to constantly monitor student progress, provide targeted feedback, and assess student's mastery [20]. All this information throughout a student's time in formal (and in some cases in informal or non-formal) educational settings might contribute to the consistent support of an individually formatted framing [17, 21]. While AI-driven tools replace high-stakes test examinations, it signals and illustrates the two sides of applying AI in education: the benefits and the challenges. Allowing students to demonstrate their competencies while they learn is advantageous. These applications (AI-enabled adaptive and continuous assessment) have been heralded as constituting a "fourth education revolution" [22, 23]. However, it is important to acknowledge at the outset that the use of AI for learning and assessment also raises various concerns that are yet to be properly addressed. These include challenges regarding their effective integration into educational practice, the lack of robust evidence for their efficacy and potential impact on teachers' roles, and broader ethical questions.

An AI-enhanced classroom for deeper learning in STEM needs research in the field and long-lasting experience in the implementation of ICT-based innovations within educational settings [17]. In proposing a tangible approach to respond to those

challenges, a consistent roadmap for the AI-enhanced classroom for deeper learning in STEM is required to facilitate the transformation of a traditional classroom into an innovative environment and allow the latter to promote the scientific exploration of subsequent development of key skills for all students [24]. In the following sections, we are presenting an AI-enhanced environment, enhanced with scaffolds and visualizations that have been designed to introduce students to scientific exploration and inquiry, while, at the same time, supporting the development of their problem-solving competence [25, 26]. We are also presenting a number of good practices that have been designed to guide the integration of the proposed environment into school practice.

2. The discovery space exploratory learning environment

2.1 Technical description

The use of the Discovery Space Exploratory Learning Environment intends to achieve simplicity at all levels to overcome the existing barriers that are currently limiting online and remote lab applications in educational practice, sharing, and exploitation outside early adopter communities. Its use focuses on simplicity for students to conduct inquiry-based learning activities with online labs in a user-friendly environment that includes scaffolds and guidance during the experimentation, for teachers to repurpose and exploit these resources without third-party interventions, for teacher communities to share practices and scaffolding solutions, and for the lab providers to offer their resources online. The system is a single-entry point for all stakeholders integrating individual labs or repositories, learning activity spaces, associated resources, and supporting communities. There is no need for teachers and students to invest in deploying or integrating the technology at their place. Following the Web 2.0 paradigm, the environment is ubiquitously accessible to everybody from everywhere at any time and continuously updated to fulfill the needs and expectations of science education individuals and communities. It consists of three main components, The Discovery Space Management System, the AI-driven Lifelong Learning Companion, and the AR/VR Interfaces:

The first, the Discovery Space Management System, is the software architecture in charge of containing and offering the different functionalities, services, and tools integrated with the Discovery Space Exploratory Learning Environment. The second, the Discovery Space AI-driven Lifelong Learning Companion, is a tutoring tool. Rather than setting out to teach the student in the manner of an instructional Intelligent Tutoring System [25], it may act as a learning companion providing continuous support, following the students' learning paths, and even helping them to decide what to learn. By offering individualized learning pathways designed to help to address their learning interests and take their achievement levels into account, while encouraging to reflect on and revise long-term learning aims. Guidance is made possible using either a companion's conventional Web interface or an intelligent chatbot with both text-based and voice-enabled interaction. The latter, the Mixed Reality Interface [27], could also offer augmentations of graphs, videos, or animations related to the phenomenon under study. Such applications have proven their efficiency to also engage low-performing students in the experimental process. Some MR innovations use AI techniques to control lifelike virtual avatars, enable voice control using natural language processing, or generate entire environments from a few starting images. When reconsidering MR in a learning context today, the general miniaturization and high integration of

computers, and recent trends in digital-supported schooling (not least due to the pandemic) provide several routes for integration and evolution. The first one is a “mobile-first” implementation for devices like smart-tablets and smartphones that are widely deployed (and increasingly so in school contexts). The second route is to employ microcontrollers and single-board computers like Arduino, BBC micro:bit, or Raspberry Pi. All of them are widely deployed in education as well and might be able to run a compelling AR experience on otherwise very versatile platforms that come ready-at-hand with standard IO-channels and visual-programming environments such as Scratch that support reaching technological inspiration and learning problem-solving skills. The third route is to concentrate on “web-first,” browser-based integration which supports the ease of deployment for teachers and students.

2.2 Benefits for the users

While using the system, students are encouraged to actively construct their own knowledge by exploring the learning environment and making connections with their existing knowledge schema [e.g., [28–30]]. An AI Learning Companion needs to assign a role to minimize the individual cognitive overload that is often associated with exploratory learning. Providing automated guidance and feedback, based on knowledge tracing and machine learning might offer a way to solve this issue [31, 32]. Even misconceptions can be addressed individually in supporting a student while performing his/her experimental task [33, 34]. The AI-driven lifelong learning companion will support students in developing their learning paths that will provide structure to the student experience and thus allow every single person to pursue goals that require extended engagement or persistence across multiple contexts and learning opportunities (see **Figure 1**).

The role of teachers in such an exploratory learning setting is that of a “facilitator,” or “orchestrator” of learning processes [35–37]. This role would be relatively easy in one-to-one student-tutor interaction but scaling it up to the number of students present in a typical classroom poses several challenges. Given the open-ended nature of tasks that students are working on, is a major challenge for the teachers to know which students are making progress, which are off-task, and which are in difficulty and in need of additional support. Such tools could empower teachers to provide evidence of students’ deeper learning, even in a context that is less subject to formal assessment, and to engage in their own inquiry into more conceptual student learning.

While using the system, students actively need to construct their knowledge by making connections with their existing knowledge schema. AI might help to minimize the cognitive overload that is often associated with exploratory learning by providing automated guidance, based on the individual learning progress. This individualized feedback includes misconceptions and proposes alternative approaches while students are performing an experimental task. The AI-driven lifelong learning companion will support students to develop their learning paths that will provide structure to the student experience and thus allow every single person to pursue goals that require extended engagement or persistence across multiple contexts and learning opportunities.

The Discovery Space Exploratory Learning Environment is designed to facilitate and support implementation scenarios of different levels of complexity. In the next section, we are presenting three such scenarios: In the first, we describe the potential that the use of such a system holds for the upgrade of everyday teaching. In the second, we explore a more demanding implementation where visualizations and animations are activated to facilitate student’s understanding of complex and invisible



Figure 1.

Students have significant difficulties to understand the wave concepts and their propagation [38]. An exploratory learning environment enabled with scaffolding and visualizations could facilitate a deeper understanding of these phenomena. For example, the Doppler effect experiment [27] allows moving a sound source relative to a listener. The sound source could be a fire truck or an ambulance while a virtual microphone transfers the sound. As in real life, the microphone input results in a change of pitch when either of the objects is moved. This miniaturized setup allows a simulation with small movements presenting a remarkable effect due to the reduced scale. Additionally, visualizing the sound wave further improves the understanding of wave propagation of relatively moving objects. Guidance (in the form of text, formulas, graphs, or animations) is augmented to the optical view of the student during the experimentation.

concepts and phenomena. The final scenario refers to a quite demanding implementation where the students have the chance to use a combination of remote and virtual laboratories to get a full experience of the scientific inquiry.

3. Good practice scenarios

3.1 Enhancing the school-lab-work: simple harmonic oscillation

In this scenario, we are focusing on the simple harmonic oscillation concepts, mostly the concepts about restoring force, characteristics of simple harmonic oscillation, velocity, acceleration, period, and energy. The concept of simple harmonic

oscillation is very important in physics because it is essential for considering phenomena of mechanical oscillation, sound, and light, as well as quantum theory. In fact, students run into a variety of problems with inconsiderate harmonic oscillation [e.g., [35]]. Most students experience misconceptions related to the frequency of the simple harmonic motion, the relationship of the rope length to the pendulum period, and the dependence of the frequency with the oscillating mass [36].

In the specific scenario, simple harmonic oscillation concepts have been reached through experimentation with a simple pendulum. A remote lab is used as it offers the opportunity for each student to perform the experiment following his/her own learning path and inquiry strategy. By using the AI Learning Companion to interact with the students during the experimentation with the pendulum, it is expected that students show a sound understanding of simple harmonic oscillation and relate to the concepts. The AI Learning Companion can activate augmentations, virtual simulations, or related graphs that can help students in their conceptual understanding (**Figure 2**).

3.2 Visualizing the invisible: why do planes Fly?

This scenario expands the limits of the school classroom. Students in the framework of a field trip have the chance to explore the forces acting on an airplane wing and their effects on it [39, 40]. Airplane wings are designed so that the airspeed above the wing is greater than that below the wing. As wings have slight upward

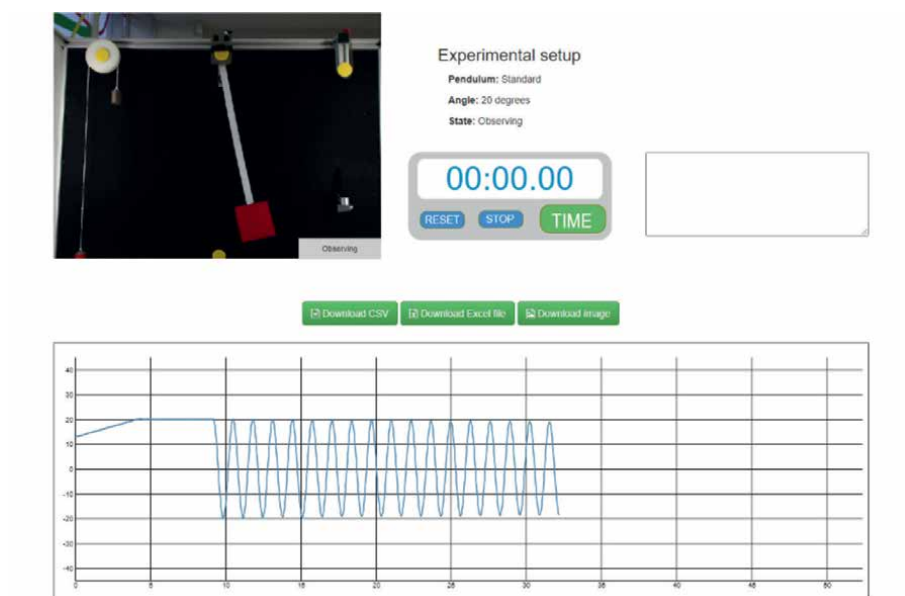


Figure 2.

The discovery space exploratory learning environment provides access to numerous remote and virtual labs to facilitate students' introduction to scientific methodology. The figure presents a remote pendulum for the study of the parameters of simple harmonic oscillation. The remote experiment is enriched with numerous augmentations that are activated on different occasions as the students experiment with the device, according to the student's level and proficiency in performing the foreseen tasks. Additional support through the activation of virtual experimentations is also provided.

tilts, air molecules strike their bottom to be deflected downwards. In consequence, wings are exerting a downward force on the air as according to Newton's third law an opposite force develops lifting the wing. Nevertheless, if wings are tilted too much, the airflow across the upper surface due to turbulences diminishes the pressure difference across the wing. The high relevance of this phenomenon to the curriculum affects numerous concepts: Forces and motion (Newton's first and third law, quantitative relationship between force area and pressure, air resistance, and drag) air pressure, and/or density. The Airplane Wing is an interactive exhibit (see **Figure 3**) using a simple fan that is operated with an illuminated push button and blows air across an experimental wing. The fan goes on for approximately 30 seconds and blows air across the wing. The wing pivots on a horizontal tube that can be tilted by the operator at a steep or narrow angle to the airflow that is blowing across it. Table tennis balls are encased in the wing, which is made of clear Perspex. The independent variable manipulated by the user is the wing and the dependent variable is the lift generated at each angle of the wing, represented by the position of the ping-pong balls. The students' interactions are based on focal research questions: How do airplanes fly? What factors influence lift? How does lift depend on these? Why do the ping-pong balls in the exhibit move up and down?

A common students' misconception is that lift is created due to Bernoulli's effect providing problems regarding the invisible nature of the phenomenon [40]. Students often (i) neglect the effect of air movement on an airplane's lift, (ii) are unaware of the presence of air pressure, especially when air is not moving, or (iii) do not analyze the lift of an airplane's wing in terms of forces. Theories of flight however are not in the curriculum at this stage, so most students probably have not thought about flight.

The AI Learning Companion will be present during the students' interaction with the exhibit providing guidance and support in students' understanding and conceptual change. As students have the chance to interact with the exhibit in different ways, the AI Learning Companion can facilitate the development of learning paths based on

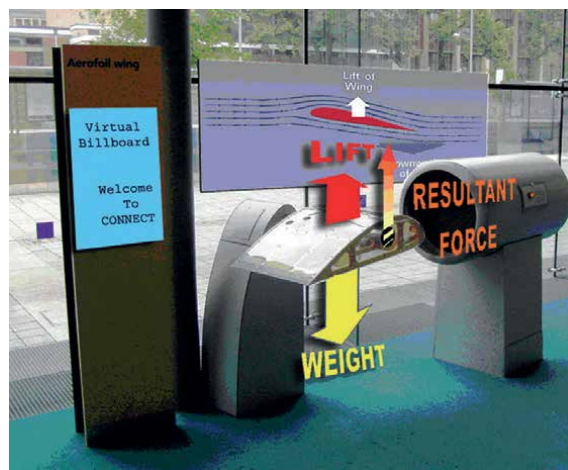


Figure 3.

The discovery space exploratory learning environment provides opportunities to expand classroom-based activities. In this scenario, the airplane wing is enriched with augmentations and visualizations that are activated while students are interacting with the wing. The augmentations offer opportunities for personalization as the students can follow their own learning path while interacting with the exhibit.

the previous experiences of the students and their understanding of the problem. In this case, the dialog between the student and the system can be enriched with images, animations, or even more advanced augmentations that could be realized according to the level of problem-solving competence of the students.

3.3 Real-life scientific inquiry: studying the collision of galaxies

The Discovery Space Exploratory Learning Environment could provide support for the involvement of students in quite complex tasks by providing personalized guidance and support. The case of remote telescopes in educational contexts is such an example. Although far distant from classrooms, a robotic telescope can be made available for undergraduates in real-life research contexts by offering an authentic experience. It can encourage curiosity just at that point of an education career where the content itself can start to become quite dry and overloaded. For continuing astronomy careers throughout undergraduate times, access to robotic telescopes might maintain curiosity and discovery appetite by making observational data available that may be taken at face value otherwise. Those students who may be continuing toward higher level courses or even deciding on a scientific career may want to dig a little deeper into astronomical research during their undergraduate experience.

By having remote or robotic telescopes accurately and automatically aligned, all the stress of setting up the telescope and pointing, which requires a lot of skill and practice, is removed from the teacher or the student. Telescopes are located at distant spots, allowing access from all over the world and requiring just a small group of professionals for maintenance [41, 42]. A variety of benefits to the telescope user are apparent: Compared to mobile telescopes more effective mounts and larger apertures are possible. Physically damage of telescopes is next to impossible, no time expenditure to set up, pack up, or maintain the instrument by users do not apply. The technical knowledge necessary for use can be minimized through a well-designed user interface.

The Discovery Space Exploratory Learning Environment provides as a user interface constant support beginning with technical knowledge substituting high initial investment cost [43]. And not to forget, there is access to either the Northern or Southern hemisphere, exceeding the one where students are physically located, opening more objects in the night sky to view. The access procedure typically involves a request within an online automated scheduler which in return provides an image (autonomous control), or through direct remote control of a telescope, located in a favorable time zone (remote control). **Figure 3** presents the interface of the Discovery Space Exploratory Learning Environment. Students must select the telescope (taking into consideration the observation target and the location of the selected telescope), set the observation parameters, and check the weather conditions in the location. The AI Learning Companion will interact with the student at different stages and will support the students' inquiry and understanding of the process [44]. A series of possible interactions are presented in **Figure 4**. These interactions will be activated by the system only if the students face difficulties in accomplishing the task and help to provide a different interpretation of the "scientific method" involving observation, simulation, and theory, rather than the typical pre-arranged experimental textbook approach commonly provided. This way of authenticity may improve an otherwise uninspiring school experience. Robotic telescopes also support strong links with pure physics, by utilizing concepts to do with light, gravity, and instrumentation. Looking at objects' sizes and ages in the Universe may offer a less abstract/theoretical basis

Remote Lab

Select the best telescope for the observation

Check the time that the galaxies are at the higher point in the sky

Check the weather conditions first!

Step 1.

Step 2.

Step 3.

Step 4.

Making the observation
Students may observe one of two the following galaxies:

M51 and its companion, NGC 5195
Coordinates: 3:29:53.16, 47:11:48.120
Filter: Color
Exposure: 180 s

NGC 4038 - The Antennae
Coordinates: 2:01:52.68, -18:51:54.00
Filter: Color
Exposure: 180 s

Filters are very important when you targeting the deep space!

Figure 4. While students are using the discovery space interface, the AI learning companion is present to support their inquiry. In the specific case, the possible interactions with the AI learning companion are indicated in the orange boxes. These interactions are activated according to the student's proficiency to handle the remote telescope interface. They are presented in a progressive way to support students' understanding of the process and to introduce them to the scientific inquiry.

Try not to change too many parameters at once in a run. See how each parameter individually affects the simulated galaxies first.

During a simulation, the image of the galaxy may not appear identical to the real one. In order to produce an image closer to the real one, students should zoom in and rotate the image.

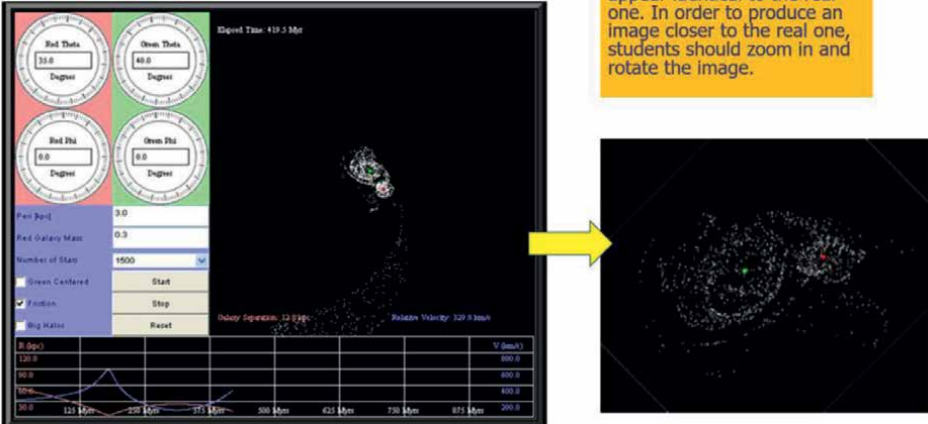


Figure 5. Students with higher levels of proficiency or great interest in the experiment have the chance to explore more advanced interventions. In this specific case, students are studying the collision of two galaxies in simulation software. The aim is to create a model that is quite close to the image they received from the remote telescope. In such a complex activity, numerous parameters must be considered. Those activities help students to demonstrate critical thinking and high levels of scientific proficiency. It is not possible to create such conditions in traditional learning environments where the teacher supports many students with different proficiency and knowledge levels at the same time.

for studying time, distance, and size scales. The general understanding of astronomy by high-school or undergraduate students is generally low, at any level, they typically also have very little knowledge of the night sky in terms of constellations and major stars, and limited practical knowledge beyond the reach of the naked eyes. The Discovery Space Exploratory Learning Environment provides additional opportunities for students who demonstrate higher levels of proficiency during the intervention [44]. For example, in **Figure 5**, we are presenting a rather complex activity where a simulation tool for modeling the crash of galaxies is used. The task that has been assigned to students who have demonstrated high levels of science proficiency and problem-solving competence is to reproduce the images they have got from the remote telescope through this simulation software. In such a way, the AI Learning Companion could optimize the instruction to meet the needs of all students, including low and high performers at the same time [45]. Such interventions are not possible in traditional classroom environments.

4. Conclusions and future developments

There is a wealth of learning science literature about supporting inquiry-based learning in Exploratory Learning Environments [46, 47] and, more specifically, in virtual labs [4]. There are several advantages of such environments: (i) By aligning with a scientific inquiry cycle students might more easily encounter a cognitive conflict between existing ideas and data that comes from experiments. Such conflicts very likely would stimulate students' adaptation to existing knowledge. This theoretical notion is closely related to cognitive theories of schema development and adaptation. (ii) Within the impetus for science learning online labs and accompanying simulations often use multiple representations [4]. These different representations (graphs, animations, equations, tables, etc.) are dynamic and must be connected by students, which leads to processes of knowledge abstraction, as also explained by Mayer's multimedia theory [48]. A third underlying principle is that in the virtual lab environment, students oversee their own learning process, which, according to theories of social learning, leads to higher motivation and especially to intrinsic motivation, while the students get control over the learning process by planning, monitoring, and reflecting about it. In this way, virtual labs also support self-regulated learning [4]. A fourth relevant theoretical approach is constructionism [47]. According to this theory, students learn through the process of identifying and representing the components that comprise a phenomenon. These components include objects (e.g., particles), processes (e.g., free fall), entities (e.g., acceleration), and interactions (e.g., how entities interact with objects or processes). In other words, the learner strips down the phenomenon into its components (an analysis process) and then builds up the phenomenon in a modeling environment (a synthesis process). However, the underlying premises behind each of these approaches could be overly optimistic; for example, sometimes students do not adapt their knowledge in response to anomalous data or they fail to connect representations [25]. In these cases, instructional support is needed for successful learning [7]. Developing the technology to support effective learning in exploratory environments still faces several significant challenges. Such an approach requires the adoption of AI platforms and data-based learning analytics as key technologies in building integrated lifelong

learning systems to enable personalized learning anytime, anywhere, and for every student. We need to exploit the potential of AI to enable flexible learning pathways and the accumulation, recognition, certification, and transfer of individual learning outcomes. Allowing students to demonstrate their competencies while they learn is advantageous, but how this might be achieved without continuous monitoring – i.e., surveillance – is less clear. Such monitoring also involves many ethical concerns [47].

The role of AI in the Discovery Space Exploratory Learning Environment is to minimize cognitive overload by providing automated guidance and feedback, based on knowledge tracing and machine learning. This feedback addresses students' misconceptions and proposes alternative approaches as well as supports their conceptual change while they explore and perform experiments. The technological innovations in Discovery Space aim at simplicity at all levels to overcome the existing barriers that are currently limiting online and remote lab deployment in educational practice, sharing, and exploitation outside early adopter communities [49]. Discovery Space focuses on simplicity for the lab providers to offer their resources online [50], for the teachers to repurpose and exploit these resources without third-party interventions, for teacher communities to share practices and scaffolding solutions, and for the students to conduct inquiry-based learning activities with online labs in a user-friendly environment that includes scaffolds and guidance during the experimentation.

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Section 5

Creative Lesson Plans

Physical and Digital Educational Escape Room for Chemical Education

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Abstract

An educational escape room uses a game-based active learning approach to develop students' critical thinking and problem-solving skills in an immersive environment. In this chapter, the authors conducted an evaluation of two physical and digital educational escape rooms that were previously developed to provide an innovative learning activity to reinforce concepts and/or address misconceptions in chemistry for general chemistry courses. The evaluation demonstrated that both educational escape rooms are highly effective as teaching tools. Students' provided positive feedback, highlighting that the educational escape rooms reinforce and motivate learning. Hence, integrating educational escape rooms with conventional lessons can offer students a holistic and captivating learning experience.

Keywords: collaborative/cooperative learning, internet/web-based learning, Student-Centered learning, game-based learning, general chemistry, inorganic chemistry

1. Introduction

Students often find chemistry challenging as they perceive it as abstract and content-heavy [1, 2]. As a result, students often resort to memorizing the content [3]. To increase engagement and motivation and to reinforce knowledge, an escape room could be used as a game-based active learning approach [4]. Educational escape rooms (EERs) have gained interest and popularity in various fields including science education in recent years [5–7]. EERs challenge students to apply conceptual knowledge to solve puzzles and complete tasks through a hands-on, interactive, and immersive experience. EERs have also been reported to enhance student engagement and soft skills, such as problem-solving and critical thinking skills [4, 8, 9].

Physical EERs are designed to be played in a physical space, such as a classroom or dedicated facility. They often incorporate props, puzzles, and challenges that require physical interaction and manipulation in a highly immersive and interactive environment. Digital EERs are designed to be played online or through a digital platform. They often use multimedia elements, such as videos, images, and audio, to create an immersive experience.

The unique and immersive experience in physical EERs can be difficult to replicate in a digital format. They allow for more flexibility in the design of puzzles and challenges to promote collaboration and communication skills. Digital EERs, on the other hand, allow for more flexibility in terms of accessibility and convenience, can be accessed asynchronously (anywhere and anytime) and allow teachers to track student progress. While both physical and digital EERs have their benefits, the choice between physical and digital EERs will depend on the specific needs and preferences of the teacher and students.

Game-based learning is a pedagogical approach that engages students in active and experiential learning [10]. This approach draws on the principles of game design and applies them to educational contexts to promote students' motivation, engagement, and learning outcomes [11]. The self-determination theory [12] and the cognitive load theory [13], provide the basis for the design and development of game-based learning environments [14, 15]. These frameworks address motivation, engagement, and cognitive processing issues and ensure that games enacted as learning activities align with educational goals and objectives. Game-based learning offers a unique perspective on designing and implementing effective teaching and learning strategies by lowering students' cognitive load [16].

The benefits associated with EERs made them a suitable teaching tool in chemical education. EERs have been increasingly used in chemical education [17–21] to promote student engagement [22–29]. Although numerous accounts exist regarding the utilization of EER in chemical education and its positive impact on student engagement, there is a dearth of studies focusing on its effectiveness in terms of academic achievement, particularly ones that rely on objective data rather than students' self-reports. This chapter focuses on the evaluation of the effectiveness of two previously developed physical and digital EERs for chemical education, which draws on the principles of game-based learning [30, 31]. In addition, students' perceptions of both the physical and digital EERs were compared. This chapter aims to contribute to the use of EERs as a worthwhile teaching tool for science education, specifically in the field of chemistry.

2. Results and discussion

A mixed-method approach was used to evaluate both EERs. The evaluation included students' achievement of learning outcomes using pre- and post-tests and their perception of EERs through a survey.

2.1 Educational escape room for the topic of chemical bonding

The design and implementation of the physical and digital EER were reported previously [31]. A quasi-experiment was conducted with students from the Diploma in Pharmaceutical Science and Diploma in Food Science & Nutrition at Nanyang Polytechnic (NYP) across the academic years (AY) 2019 and 2020. In this study, participants completed a pre- and post-test and the difference in scores between the pre- and post-test was used to determine the effectiveness of the intervention. Students' perceptions of the interventions were determined through an anonymous survey.

A class with approximately 24 students were randomly split into three groups (groups A, B and C) of approximately 6 to 8 students (**Figure 1**). Before engaging in the intervention as a learning activity, all students took a pre-test. Groups A and

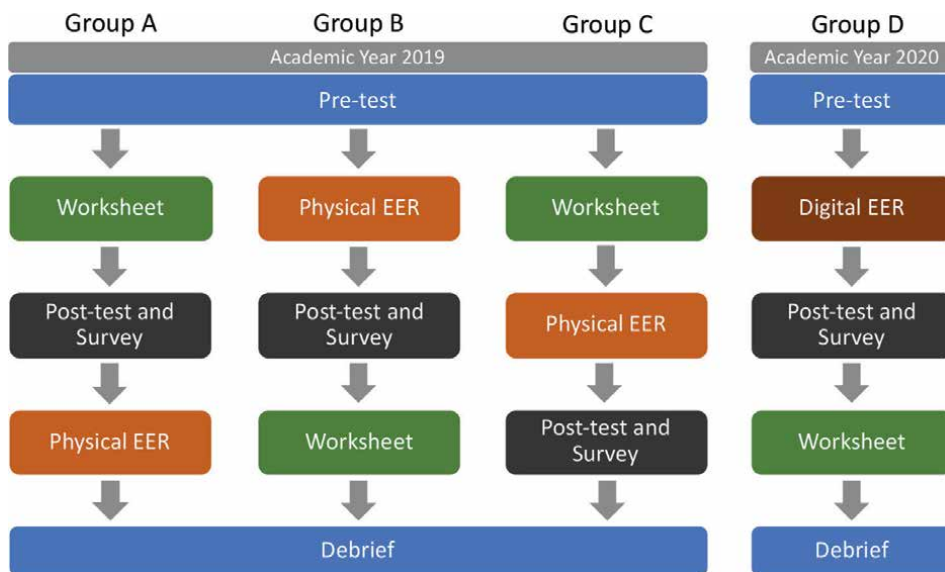


Figure 1.
 The research design for the chemical bonding EER study.

B were exposed to different interventions: Group A received a typical tutorial worksheet, while Group B experience the physical EER. The purpose was to evaluate the effectiveness of the interventions in learning the topic of chemical bonding. Group C, on the other hand, experienced both the tutorial worksheet and physical EER before taking the post-test. Immediately after completing the post-test, all students filled out an online survey. Following the survey, Groups A and B underwent the other intervention to ensure equal learning experiences for all students. At the end of the 2-hour lesson, students were provided with feedback on their test answers and were given an overview of the study.

Due to the COVID-19 pandemic, the implementation of the physical EER was not feasible. Hence, in AY 2020, a digital EER was developed as an alternative to the physical EER. Although the digital could be completed individually or in groups, in this study, students completed the digital EER in groups of four via a video conferencing platform. For this group of students (group D), the research design was similar to group B, except that the physical EER was replaced with a digital EER (**Figure 1**) and the group size was smaller.

Table 1 shows the mean scores of the pre- and post-test in each group. All interventions showed a gain in the mean scores, indicating that students' academic achievement for this topic increased. Students who experienced the physical EER (group B) showed the greatest improvement (34.8%). Students who experienced the digital EER (group D) showed a lower percentage increase (27.5%). This could be attributed to the distanced learning experience and the increased transactional distance [32] among the students, teachers and their peers. It is worth noting that students who experienced both the worksheet and physical EER (group C) had a lower percentage increase (27.4%) compared to physical EER alone. This could be because students were cognitively fatigued after completing two interventions [33].

All students completed a survey after the post-test, and the survey results were summarized in **Tables 2** and **3**. The survey used a four-point Likert scale (1 = strongly

Group	A (N = 44)	B (N = 44)	C (N = 41)	D (N = 61)
Pre-test mean score (max score = 10)	5.02	6.00	5.44	6.52
Post-test mean score (max score = 10)	6.18	8.09	6.93	8.31
Percentage increase	23.1	34.8	27.4	27.5

Table 1.

Pre- and post-test mean scores for chemical bonding EER.

disagree, 2 = disagree, 3 = agree, 4 = strongly agree). The survey items (**Table A1**) consist of five subscales: Interest/enjoyment, perceived competency, value/usefulness, relatedness, and extrinsic motivation adapted from the Intrinsic Motivational inventory [34] and Extrinsic Incentives [35] and modified according to the type of intervention. **Table 2** shows the mean scores for the individual items and **Table 3** shows the mean scores for the subscales. As the tests and the survey were conducted on different platforms, some students chose to participate in either the tests and/

Subscales	Items	Group A (N = 56)	Group B (N = 53)	Group C (N = 21)	Group D (N = 53)
Item mean (SD)					
Interest/ Enjoyment	1	2.50 (0.76)	3.53 (0.54)	3.38 (0.50)	2.70 (0.85)
	2	2.66 (0.84)	3.53 (0.64)	3.52 (0.60)	2.96 (0.81)
	3*	2.61 (0.95)	1.49 (0.70)	1.71 (0.78)	2.17 (0.89)
	4	2.59 (0.91)	3.47 (0.64)	3.38 (0.50)	2.58 (0.80)
	5	2.66 (0.82)	3.42 (0.63)	3.33 (0.58)	2.57 (0.80)
Perceived competence	6	2.18 (0.88)	2.34 (0.78)	2.33 (0.97)	2.17 (0.73)
	7	2.27 (0.75)	2.51 (0.75)	2.62 (0.74)	2.21 (0.74)
	8*	2.68 (0.86)	1.92 (0.83)	2.19 (0.75)	2.47 (0.80)
Value/ Usefulness	9	2.57 (0.85)	3.32 (0.73)	3.43 (0.60)	2.40 (0.84)
	10	2.98 (0.70)	3.71 (0.75)	2.95 (0.74)	2.70 (0.85)
	11	3.09 (0.67)	3.13 (0.73)	3.19 (0.68)	2.64 (0.79)
Relatedness	12	2.79 (0.82)	3.23 (0.67)	3.33 (0.58)	2.49 (0.75)
	13*	1.89 (0.89)	1.51 (0.70)	1.67 (0.97)	1.81 (0.74)
	14	3.07 (0.74)	3.47 (0.61)	3.43 (0.60)	2.70 (0.70)
	15	2.89 (0.85)	3.42 (0.63)	3.52 (0.60)	2.62 (0.90)
Extrinsic motivation	16	2.71 (0.65)	2.96 (0.73)	2.76 (0.77)	2.51 (0.80)
	17	2.55 (0.83)	2.55 (0.93)	2.24 (0.94)	2.00 (0.85)
	18	2.95 (0.75)	2.96 (0.85)	2.62 (1.02)	2.28 (0.79)

*Reverse question, item mean was reversed before calculating the subscale mean in **Table 3**. This is to measure the same construct as the other questions, but are phrased in an opposite manner to detect and control for response bias.

Table 2.

Descriptive statistics of students' perception of the learning activities (tutorial worksheet, physical EER, and/or digital EER) based on individual items.

Subscales	Group A (N = 56)	Group B (N = 53)	Group C (N = 21)	Group D (N = 53)
Subscale mean (SD)				
Interest/ Enjoyment	2.56 (0.86)	3.49 (0.63)	3.38 (0.59)	2.73 (0.83)
Perceived competence	2.26 (0.83)	2.64 (0.79)	2.59 (0.82)	2.30 (0.76)
Value/ Usefulness	2.88 (0.74)	3.39 (0.74)	3.19 (0.67)	2.58 (0.83)
Relatedness	2.97 (0.83)	3.40 (0.65)	3.40 (0.69)	2.75 (0.77)
Extrinsic motivation	2.74 (0.74)	2.82 (0.84)	2.54 (0.91)	2.26 (0.81)

Table 3.
Mean scores of each survey subscale for all groups of students.

or the survey, leading to the different sample size. As expected, the results for the worksheet group (group A) were low and the results for the physical EER were the highest. It is interesting to note that students' perceptions of the worksheet and digital EER were similar. Despite the lower percentage increase in academic achievement for group C, students' perception was similar to group B. Hence, students were still motivated to complete the physical EER after the worksheet, but two back-to-back learning activities resulted in cognitive fatigue [33].

The mean scores of reverse questions (i.e. those marked with an asterisk in **Table 2**) were reversed before calculating the subscales' mean scores.

In the survey, students were also asked qualitative questions to triangulate the quantitative data. Based on their responses, students felt that they were able to apply what they have learnt by solving the puzzles in a fun and exciting environment. It also allowed them to work with one another to solve the puzzles which is an enjoyable and memorable experience. On the other hand, the digital EER has posed challenges such as communication with their peers and the lack of interactivity due to the remote nature of the digital EER. However, students still felt that digital EER was effective in general.

2.2 Educational escape room for general chemistry topics

Following the development and implementation of the chemical bonding EER, an EER for general chemistry topics was also developed. The design and implementation of the digital EER for stoichiometry were reported previously [30]. A quasi-experiment was conducted with 38 students from the Polytechnic Foundation Program (PFP) under the Applied & Health Sciences cluster in NYP who participated in this study. Similar to the first study, pre- and post-tests were administered to determine the effectiveness of the intervention in addressing misconception. The effectiveness was measured through the increase in academic performance (mean score) for the relevant topic. Students' perception of the digital EER was determined through an anonymous survey.

The participants formed three groups with the first group as the control with no intervention, the second group went through an online synchronous lesson, while the third group experienced the digital EER (**Figure 2**). To ensure all participants had the same learning experience, students underwent the other interventions before completing the survey.

Four topics in general chemistry (balancing chemical equations, calculating empirical formulae identifying the types of chemical bonding and interpreting

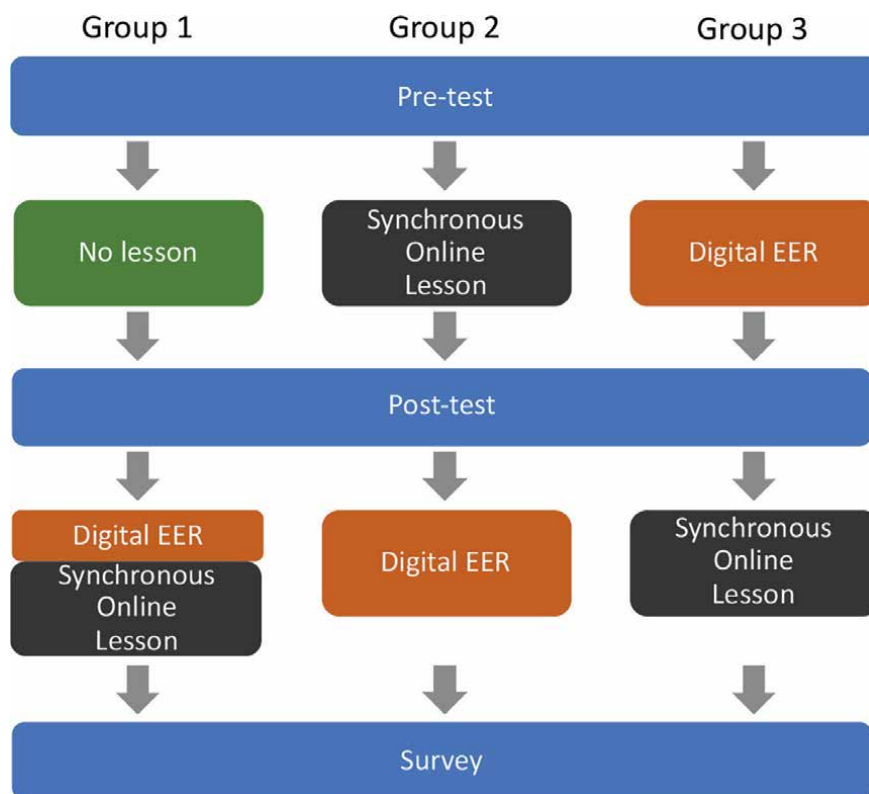


Figure 2.
The research design for the stoichiometry EER study.

element symbols) were included in the pre-test. Based on the mean scores, it was clear that students found determining empirical formulae challenging (**Table 4**).

Upon analyzing the pre-test responses of students, it was found out that students have misconceptions in determining the empirical formulae. This conceptual error has led to a low score in that specific topic. According to Chi [36], a concept has both perceptual features and conceptual attributes and can be viewed as belonging to the explanation-based or principle-based categories. To address the misconception, students must undergo the process of conceptual change, where an existing conception is replaced with a new conception. Kuhn [37] developed the Kuhn cycle for conceptual change which ends with a paradigm change where a new reality can be explained by a new paradigm. Conceptual change also draws from Piaget's concepts of assimilation and accommodation which are situated in Piaget's learning theory of cognitivism [38].

Topic	Balancing chemical equations	Determining empirical formulas	Identifying the types of chemical bonding	Interpreting element symbols
Mean score (N = 38, max score = 10)	8.95	6.05	9.58	8.97

Table 4.
Pre-test mean scores for each of the general chemistry topics.

Group	1 (N = 11)	2 (N = 10)	3 (N = 17)
Pre-test mean score (max score = 10)	7.27	5.50	5.59
Post-test mean score (max score = 10)	7.27	6.00	6.18
Percentage increase	0	9.1	10.6

Table 5.
Pre- and post-test mean scores for determining empirical formulae topic.

In addition, the social and/or affective dimension has also been reported as part of the multidimensional framework for conceptual change [39]. This framework further supports the learner-centred collaborative learning feature found in most EERs.

The study focused on the topic of determining empirical formulae to evaluate the effectiveness of using digital EER in addressing misconceptions and facilitating effective conceptual change. After the pre-test was administered, group 1 was assigned as the control group due to their higher pre-test mean scores for the determining empirical formulae topic. Groups 2 and 3 were randomly assigned to either intervention. The students then took a post-test. The mean pre- and post-test scores for the topic of determining empirical formulae showed that for both groups 2 and 3, there is an approximate 10% increase in the mean scores (**Table 5**). This result is not surprising because intuitively having some form of intervention is more beneficial than no intervention. Comparing a typical synchronous online lesson (group 2) to digital EER (group 3), the digital EER group had a slightly higher percentage increase in their mean scores. With this, it can be concluded that the digital EER is as effective, if not better, than a typical synchronous online lesson in addressing misconceptions.

Subscale	Item	Item mean (SD)	Subscale mean (SD)
Motivation/ Interest	I enjoy participating in the escape room.	3.42 (0.68)	3.36 (0.72)
	I find the digital escape room more interesting.	3.42 (0.76)	
	I participate more actively in the digital escape room.	3.39 (0.68)	
	I feel more motivated when participating in the digital escape room.	3.21 (0.74)	
Teamwork	The escape room promotes teamwork.	3.66 (0.63)	3.66 (0.63)
Innovation competency	I develop and experiment with new ways of problem solving when participating in the escape room.	3.16 (0.89)	3.19 (0.86)
	I use trial and error for problem solving when participating in the escape room.	3.24 (0.85)	
	I think differently and adopt different perspectives when participating in the escape room.	3.18 (0.83)	

Table 6.
Descriptive statistics of students' (N = 38) perception of the digital EER compared to a typical synchronous online lesson.

Besides the slightly higher percentage increase in the mean score for digital EER, students also had a better perception of the digital EER as a teaching tool over the typical synchronous online lesson. The survey used a four-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree). The results of the survey showed that students found the digital EER more interesting compared to a typical synchronous online lesson (**Table 6**). They were also willing to participate more actively as they were more motivated. Besides the increase in academic performance, students also reported additional benefits such as increased teamwork and the development of innovation competency.

In the survey, students were also asked to qualitatively indicate what they liked about the digital EER. Students enjoyed the freedom when completing the digital EER. This could be attributed to the open structure of the EER where students could solve the tasks with no restrictions in terms of the order. Students also liked that the digital EER could promote teamwork, and was fun, interesting, and engaging. This aligned with the quantitative data where the mean scores for motivation/interest and teamwork subscales were high (3.36 and 3.66 respectively).

3. Limitations

While the existing research highlights the potential benefits of EERs in chemical education, it is important to acknowledge and address various challenges and limitations. One significant challenge is the time and resource constraints, particularly when it comes to physical EERs. The development and maintenance of physical resources, such as laboratory setups or interactive models, often require substantial investments of time, effort, and funding. Educators must carefully consider these limitations and assess the feasibility of implementing such resources within their specific educational context.

Another challenge lies in the design of appropriate tasks that effectively leverage the potential of EERs and align with the learning objectives. Tasks should be thoughtfully crafted to encourage active participation, critical thinking, and problem-solving skills among students. Ensuring that the tasks are engaging, meaningful, and directly relevant to the learning goals can significantly impact the effectiveness of EERs in facilitating conceptual understanding and knowledge retention.

Additionally, catering to the diverse needs of students is essential to foster inclusive learning experiences. EERs should be designed with flexibility and accessibility in mind, allowing for adaptations to accommodate different learning styles, abilities, and preferences. Considering the diverse backgrounds and abilities of students promotes a more inclusive educational environment and ensures equitable opportunities for all learners.

Furthermore, the topics covered in this study were not exhaustive, as the focus was primarily on general chemistry. Exploring additional topics from different areas of chemistry would provide a more comprehensive understanding of the impact of EERs across the discipline. In addition, the smaller sample size, especially in our second study, could potentially affect the generalizability of the findings. To enhance the reliability and validity of future research, expanding the study to include a larger group of students would be beneficial. This would allow for a more representative sample, thus increasing the generalizability of the study's results.

4. Conclusions

In conclusion, both pieces of research on physical and digital EERs in chemistry courses highlight the effectiveness of game-based learning approaches in education. The physical EER for chemical bonding successfully facilitated critical thinking and problem-solving skills, encouraged discussion, and promoted collaborative problem-solving. While the physical EER was modified into a digital format due to the COVID-19 pandemic, student feedback affirmed the value of both approaches in reinforcing learning. Furthermore, the digital EER for stoichiometry not only proves to be as effective as traditional online lessons with collaborative learning methods in addressing misconceptions but also offers the additional advantages of fostering teamwork, time management skills, communication abilities, innovation competency, and student motivation. Therefore, incorporating EERs alongside traditional lessons can provide students with a comprehensive and engaging learning experience in immersive environments.

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Conflict of interest

The authors declare no conflict of interest.

Appendix

Subscales	Item No.	Survey Items (Group A)	Survey Items (Group B, C and D)
Interest/ Enjoyment	1	I would describe doing the worksheet as very interesting.	I would describe this escape room as very interesting.
	2	Doing the worksheet was an interesting way to learn.	Playing the escape room was an interesting way to learn.
	3	Doing the worksheet was a boring activity.*	Playing the escape room was a boring activity.*
	4	Doing the worksheet was fun.	Playing the escape room was fun.
	5	Doing the worksheet was quite enjoyable.	Playing the escape room was quite enjoyable.
Perceived competence	6	I do the worksheet well compared to other students.	I play well in the escape room compared to other students.
	7	I was quite good at doing the worksheet.	I was quite good at playing the escape room.
	8	I was unable to do the worksheet well.*	I was unable to play the escape room well.*

Subscales	Item No.	Survey Items (Group A)	Survey Items (Group B, C and D)
Value/ Usefulness	9	I would be willing to do the worksheet again because it was valuable to me.	I would be willing to play the escape room again because it was valuable to me.
	10	I believed I learnt about the topic while I was doing the worksheet.	I believed I learnt about the topic while I was playing the escape room.
	11	I believed doing the worksheet was beneficial to me.	I believed playing the escape room was beneficial to me.
Relatedness	12	I felt close with my peers while doing the worksheet.	I felt close with my peers while playing the escape room.
	13	I did not feel like I could really trust my peers in doing the worksheet.*	I did not feel like I could really trust my peers in playing the escape room.*
	14	I like to do the worksheet with my peers because we could achieve something together.	I like to play the escape room with my peers because we could achieve something together.
	15	Doing the worksheet provided more chances to interact with my peers.	Playing the escape room provided more chances to interact with my peers.
Extrinsic motivation	16	Doing the worksheet helped me to improve my grade.	Playing the escape room helped me to improve my grade.
	17	I want others to know that I am a good student if I do the worksheet well.	I want others to know that I am a good student if I play the escape room well.
	18	I want to do the worksheet well so that my effort will be recognized by my classmates.	I want to play this escape room well so that my effort will be recognized by my classmates.

*Reverse questions to measure the same construct as the other questions, but are phrased in an opposite manner to detect and control for response bias.


Table A1.
Survey items for chemical bonding EER.

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Increasing E-Learning Modalities through Creative Use of Technology in the Post-Pandemic Era

Thirumeni T. Subramaniam and Ismail Md. Rosli

Abstract

The post-Pandemic Era leaves us with the question of whether to pursue the move toward digital education or step back into face-to-face education. The reasons for the debate can vary from the lack of infrastructure to stringent national qualification agencies. Regardless, the pandemic has taught us to be adaptable. As such, progress must be made in both formats, digital and conventional education. In moving e-learning forward while coping with diverse needs of global education across geographical, age, ethnicity, and socioeconomic boundaries, the inclusion of read, watch, and listen (RWL) modalities becomes essential. Successful deliveries of different modalities lie in creativity and creative use of technology that is driven by the achievement of targeted learning outcomes. This chapter attempts to discuss the experience of creating RWL modalities by embracing the universal design, and other creative use of technology to develop twenty-first century learners.

Keywords: creativity, E-learning modalities, post-pandemic era, technology, universal design

1. Introduction

The post-pandemic era refers to the present era after the outbreak of the coronavirus (COVID-19) pandemic that originated from Wuhan, Hubei Province, China in December 2019. By the end of January 2020, the cases have reported in 18 countries outside China. On 11 March 2020, the World Health Organization made the assessment that COVID-19 can be characterized as a pandemic as a result of the alarming levels of spread, severity, and inaction [1]. Localized lockdown started in China on 23rd January 2020. In Sri Lanka, national recommendations for lockdown were issued around the same time even before the first case was reported in the country [2]. By early April 2020, over a third of the global population was under some form of lockdown or movement control. It is only on 5th May 2023 that WHO declared an end to COVID-19 as a public health emergency, but cautioned that it may still remain as a global threat [3]. As of 24th May 2023, WHO reported 766,895,075 confirmed cases and 6,935,889 deaths, with more than 13 billion vaccine administered. Today, there a still new cases that are being reported. On 22nd May 2023, the number of newly reported cases was 45,769.

The impact of the pandemic lockdown is far-reaching into crucial aspects of daily life of the people, including food security, healthcare, mental health, domestic violence, global economy, air quality, education, death, and others [4]. Of these, the only good news is the improvement of the air quality throughout the world. The same improvement is not certain for the environment. While the amount of waste produced ought to have decreased with reduced economic activities, particularly with reduced tourism activities an increase in environmental waste in the form of newly created medical waste, as well as household waste was observed [5]. In addition, there challenges to the recycling efforts that have been implemented prior to the pandemic. During the lockdown, schools and higher education institutions had to be closed. The closure is inevitable, and the global community did not have the time to plan the transition; immediate actions were required in order to proceed with provision of education through the only mode that would support it under the lockdown, the online mode of education. For most, it is a question of implementing the most probable solution and revisions as the global community struggle through the pandemic era amidst all other impacts of COVID-19. The following introspection is focused on the exploration of the impact of the pandemic on education and the direction to be taken in the present post-pandemic era.

In exploring the education dilemma in the post-pandemic era, the necessary conditions and choices are explored, including inclusivity as a condition, the role of technology in education, the importance of creativity in content delivery and learning space, and practical e-learning modalities. The aim of this chapter is to improve our understanding of the impact of the pandemic on education and how best to move forward by constructing a post-pandemic education service that not only meets the sustainable developmental goal 4 or SDG 4 targets but also ensures a service that is risk tolerant, inclusive, adaptable and able to meet both, local and global requirements.

2. Education dilemma in the post-pandemic era

One major impact of the pandemic to education is greater acceptance of digital education, as well as open (and distance) education. During the pandemic, education had to be carried out completely through the online mode, thus forcing everyone to accept it as a mode of education. This acceptance is particularly important to all open universities around the world. Large corporations have been exploring knowledge management infrastructure as part of their effort in transformation as a learning organizations. Even smaller organizations have websites that provide basic knowledge in their area of industry as a marketing technique. The pandemic has helped to expedite the growth and advancement in this area. Today job-related skill development through online courses (short courses, massive open online courses, open educational resources (OERs) have become a big part of work life. Lifelong learning has become a culture in today's society. The involvement of reputable industry players in the offer of online courses through platforms such as Coursera alongside university online courses simply proves that the education services are no longer in the purview of few, but individuals can choose how they want to construct their own knowledge portfolio.

The question is whether such wide opportunity exists for all individuals, hence the need to explore digital divide and how it be closed. Digital divide refers to the gap that exists between those who have the access to information and communications technology (ICT) and those who do not and those who have limited access.

Resource needed varies from ICT hardware and software, internet access, or stable internet connection, and even stable electric supply. As suggested in **Figure 1**, differences in economic power between regions leads to noticeable gaps between one region to another. Gap also have been found to exist among different generation and different gender. Digital divide must be acknowledged as one of the world's most important crisis due to the fact that it increases inequality among individuals. The most critical issue arising from digital divide is access to education. Another important issue is the huge limitation to access to work. Much of today's job requires digital skills and greater opportunities lie in the realm of the digital world. Mental health caused by social isolation, particularly during the pandemic is another problem that is being explored extensively in the post-pandemic era. In addition, there are new crimes brought about by the digital world. Thereby, creating a new form of vulnerable group of people (those who are marginalized by the digital divide). Digital divide also translates into other forms of divides such classes of economies, and thus social.

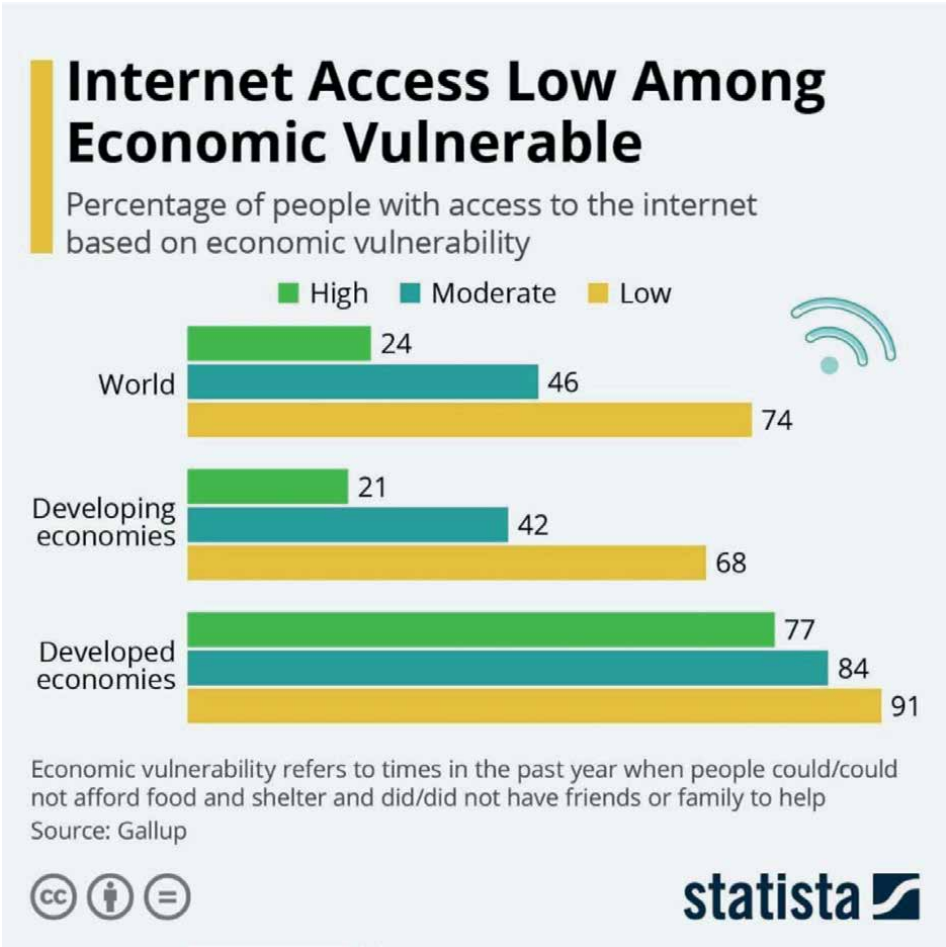


Figure 1.
Internet access low among economic vulnerable [6].

The education dilemma in the post-pandemic era is a result of the digital divide. Those with access can focus their entire attention and resources in the offer of quality digital education along with quality physical education, a hybrid with greater preparedness to switch between the options. Those with limited access may still be able to offer a hybrid solution with a good balance between online and offline resources. Those without may feel the pressure to revert back to business as usual and continue to be disadvantaged by the impacts of the digital divide. Options such as portable basic home learning kit accompanied with instructions might be a solution that could be factored in. There are also the individual differences in access to be considered. The challenges are real and must be well-understood before a workable solution is implemented. Many are debating the question whether a physical infrastructure is still necessary [7]. Among children who are beginning to build their social skills and confidence, a protected physical infrastructure is important. Young adults' need for physical infrastructure may differ based on their personalities and home settings. Even among the extroverts, the comfort of the flexibility offered by the digital world may lead them to opt for a hybrid setting rather than the pre-pandemic setting.

The above glimpse of the diverse education setting only necessitates that a solution in the provision of quality education as envisioned in the fourth sustainable development agenda, the local capacity, resources, and available support must be considered. Risk of a possible similar situation must be considered [8]. Post-pandemic education services must be developed with adaptability that enables a switch between a group/classroom setting and individual setting. It must be risk tolerant. Universal design learning must be an integral part of the curriculum design. Diversity must be not only viewed from regional or institutional setting but also in terms of individual differences in terms of skill, resources, and support needed. It must be 'glocalized'. In this, the word 'glocalization' refers to considerations of local conditions while adhering to global standards in the provision of post-pandemic education services. Meanwhile, concentrated efforts, both at national and international levels must be focused toward closing the digital divide and ensuring access to digital world for all. A global dialog such as those organized by the International Council for Open and Distance Education (ICDE) helps to bring forward the challenges, possible support and solutions for practical implementations.

3. Universal design for learning

Universal design for learning (UDL) refers to an approach that aims to build inclusive learning settings that meet the diverse needs and capabilities of learners, including those with disabilities. It requires designing instructional materials, procedures, and assessments that are accessible and successful for a wide range of learners, regardless of their characteristics or learning styles. Universal design benefits people with functional limitations and society as a whole. It supports people in being more self-reliant and socially engaged [9]. Inclusive education is enabled by incorporating universal design principles in education. These principles must be set as conditions in the delivery of digital education to ensure equal access to quality education is available to all.

The notion of UDL evolved from the discipline of architecture, which was concerned with designing buildings and spaces that are accessible and useable by everyone, regardless of an individual's physical ability. The universal design principles were then applied to other fields, including education to provide equal

educational opportunities for all learners. UDL provides a guideline to educators that would help them introduce learning designs that can create an inclusive learning environment that meets the needs of all learners with diverse learning abilities and preferences.

3.1 Seven principles of UDL

In applying universal design in learning, it is important to understand the principles of UDL. There are seven principles, which can be applied to any design of learning style; they are timeless and adaptable [10–12].

3.1.1 Principle 1: equitable use

The primary premise is equitable use, which is the driving force for accessibility. The principle encourages us to consider learners with varying capacities. When applying this idea, we must consider all learners, not just the intended learners. When we design for all learners, we improve the experience for our target learners while also increasing the value of our delivery.

3.1.2 Principle 2: flexibility in use

Nobody is the same as anyone else. A rigid and inflexible design can never accommodate all learners. This principle promotes flexible, adaptable, and/or adjustable design. It considers individual preferences and allows users to pick how they will use it. When we provide our learners with options, they will feel empowered and in charge of their online experience.

3.1.3 Principle 3: Simple and intuitive use

One of the goals of user experience design is to make things easy to use. This principle seeks to lessen complexity and mental or cognitive demands. According to the cognitive load theory, humans can only process 3–9 items in a short period of time when processing information. To lessen complexity and cognitive load, we should aim to present information between three and nine items.

3.1.4 Principle 4: perceptible information

Learners heavily depend on information. We need to ensure the content is easy to absorb and obtain, whether it is delivered through text, graphics, audio, or videos. Start with our learners when incorporating this principle into our design. We also need to consider learners with disabilities, such as those with vision or hearing impairments, when determining how best to convey information.

3.1.5 Principle 5: tolerance for error

Errors are unavoidable among people. We should design for an error-free environment. Universal design seeks to design for all learners and to anticipate varied contexts and learner activities. This idea drives us to look beyond the screen and how the system and learner will interact with each other.

3.1.6 Principle 6: low physical effort

The design allows for efficient, comfortable, and fatigue-free use. Many learners spend a lot of time on computers or laptops to complete their tasks. It is physically demanding on their bodies. Those with physical abilities have even more trouble than other learners. Therefore, it is critical to design for low physical efforts to bear in mind whenever we work.

3.1.7 Principle 7: size and space for approach and use

As digital designers, the focus is less on form factors and more on what is on the screen. This is a shortsighted perspective because it is critical to think outside of the screen and consider our learners' environment, especially as users visit websites not just on desktops but also on mobile devices, which is becoming more common. We may use the idea and its rules to create a universal design website that works on both desktop and mobile devices.

3.2 Addressing inclusivity in technology-enhanced education

Inclusive education has been the prime discussion among educationists over the years to ensure the accessibility to equal education, especially in technology-enhanced education conditions. Educational equity is the inclusion of teaching strategies to guarantee that diverse learners can access and demonstrate advanced-level information.

An important form of diversity is the different abilities at which individuals can operate. Limitations of abilities often termed as disabilities. Disabilities are part of human conditions, and it is expected that many people will experience some form of physical disabilities or impairments in their bodies during their lifetime [13]. A disability may be temporary or permanent [14]. Inclusive education not only ensures that individuals with disabilities receive an education but it is also designed to ensure that these individuals have access to the same degree of education and educational opportunities as everyone else.

The COVID-19 pandemic has brought a different educational landscape to teaching and learning. The transition from face-to-face to virtual teaching revealed the critical need for flexibility and supportive learning modalities for learners and academic staff who may be unfamiliar with these learning formats.

Not each and every student is able to have equal access to technology, for instance, laptop, smartphones, tablets, or good internet connections. Disadvantaged communities, rural areas, and countries with poor infrastructure are especially impacted by the technological gap. It is essential to ensure that students have access to appropriate devices and dependable internet connectivity in order to prevent excluding them from technology-enhanced education.

The cost of digital devices and internet services can be exorbitant, particularly for low-income students. Lowering the cost of internet service for this community can help close the gap, making technology-enhanced accessible to all.

Diverse languages and cultural backgrounds must be considered in technology-enhanced education. Due to linguistic issues, students who are not proficient in the language of instruction definitely be excluded. To support inclusive learning experiences, multilingual resources, translation services, and culturally relevant content should be made available.

Learning disabilities or special needs individuals require additional assistance and accommodation to ensure their participation in technology-enhanced education. As such, universal design should cater for all to access and functions such as text-to-speech, screen readers, and other inputs.

Marginal communities often face challenges in technology-related fields, and this can be extended to technology-enhanced education where the gap continues to widen. Some countermeasures need to be considered to encourage the participation of these marginal groups of society.

The utilization of technology involves a lot of individual data and information. Therefore, it is a necessity to protect and safeguard personal information to ensure data privacy maintains trust and inclusivity.

Having mentioned the above, joint efforts from educators, policymakers, technologists, and stakeholders are necessary to ensure inclusivity in technology-enhanced education that can be a powerful instrument for all.

4. The role of technology in education

Observations are used to discuss the role of technology in education instead of stating the intended technology role in education. Primarily, technology has enabled a connected global world that allows people the opportunities to access content and engage with experts and peers from all around the world across most forms of boundaries; thus, a global education. It is possible for learners to gain such access without leaving their homes. The most important benefit of global education is the exposure to various content, systems, and supports increases learner's awareness on differences in the quality of the content. This awareness is not only present among learners but also among educators and educational institutions. Such positive competition helps to increase the need to produce high-quality education services and support systems among many institutions across the world [15]. An environment that can support the achievement of SDG 4.

Such setting also increases the diversity of an online classroom that is usually experienced in a physical classroom. The diverse needs of global education across geographical, age, ethnicity, and socioeconomic boundaries provide a greater opportunity to understand diversity and create learning environment using the UDL principles. Use of technology in education can easily provide read, watch, and listen (RWL) modalities under a single platform and thereby meeting diverse learning preferences. Technology can also be used to foster the use of the fourth modality, kinesthetic modality [16]. Technology can help to create virtual spaces that can be shared and experienced by everyone to promote the development of kinesthetic skills. These four different modalities merely highlight how technology can integrate them and provide a diverse learning path on a single platform. Thus, the role of technology is to integrate various supports that cater for all other forms of diversity, refer **Table 1**. Careful design is essential.

The third role of technology in education is enable effective achievement of the aim of education efficiently for every individual. The challenges deliberated suggest that this is by no means an easy task, but not an impossible task. Collective efforts must be pursued through basic plan, do, check, and act cycle or ID models in order to achieve the targeted purpose. While, the process often includes evaluation, analysis, and critical thinking to ensure continuous improvement; creativity in the use of technology is important in creating a digital learning space that is efficient [17]. Successful deliveries of different modalities lie in creativity and creative use of technology, that is. driven by the achievement of targeted learning outcomes that supports the targeted education outcomes.

Demographic factors	Personal preferences	Social structures	Education level/skills
Age	Learning styles	Socioeconomic status	Qualification
Gender	Motivation	Field of work	Digital skills
Sexual orientation	Attitude	Social class	Language skills and numeracy
Ethnicity	Behavior	Marital status	Financial literacy
Religion	Expectation	Parental status	Environmental literacy
Disabilities	Emotional intelligence/anxiety	Cross-cultural	International engagement
	Physical appearances	Political affiliation	health and civic literacies

Table 1.
Classes of diversity.

Much of the future job skills are technology-related. Technology has created an intricate social network that can support far-reaching collaborative network. The skill to collaborate is a key people skill that is also an essential part of the set of future skills [18]. Social networks must be carefully selected and wisely used in order to effectively support your work network, foster collaborations and increase your learning curve. People skills, such as ability to collaborate and communicate, are crucial skills that can help one stay relevant in the increasingly challenging digital work environment. Technology and lifelong learning culture can pave the path to ensure that an individual is future job ready, adaptable, and is well-supported in coping with the challenges of the changing world, where digital world is the new reality.

The role of technology in education is, thus, revisited and realigned as the following:

- Increase access to quality glocalised education
- Create an inclusive learning environment
- Improve effective and efficient achievement of educational outcomes
- Supports the development of future skills

5. Creative content and learning space

In the educational context, creative content refers to instructional materials, tools, and activities used to enrich the educational process. Creative content in education comes in different forms such as digital multimedia, gamification, project-based learning, visual and graphic representations, and others.

In a physical setting, a learning space refers to an environment such as a classroom, where teaching and learning occur. The term may also refer to an indoor or outdoor location. A learning space could also exist in a digital platform. A digital learning space is highly diverse in use, configuration, environment, and educational institution. Contents are in the form of learning materials, interactions, and assessment, located in a digital learning space.

Both creative content and virtual learning space are interrelated to twenty-first century learning skills. It emphasized four key elements, which are communication, collaboration, creativity, and critical thinking, also known as the 4 Cs [19]. In relation to creative learning skills, when learners engage with creative content, they nurture their creativity and express themselves in unique ways. It allows for self-reflection, exploration, and artistic and imaginative skills development.

Learners utilize critical thinking when they need to think critically, synthesize data or information, and solve problems. Therefore, creative content embedded with instructional design elements promotes higher-order thinking skills (HOTS) in which learners can apply knowledge creatively and innovatively to their learning activities. Higher order thinking skills (HOTS) refers to the ability to apply knowledge, skills, and values in reasoning, reflection, problem-solving, decision-making, innovating, and creating something new [20].

Collaboration and communication skills are applicable in creative content where various kinds of creative content can help to develop vital social and teamwork skills while fostering a sense of community in the classroom through group projects or interactive discussions. As such, these activities must well-designed to encourage collaboration and communication among learners.

Beside the above relation to twenty-first century learning skills, creative content also benefits learners in many ways such as retention and application of knowledge, multimodal learning, and personalization and differentiation. By creating links and linkages with real-world situations, creative content enhances learning retention. When expose to innovative and interesting learning tools, learners are more inclined to retain the material while applying it in real-world settings.

Visual, audio, video, and interactive elements are just a few examples of the many media and formats that creative content frequently combines. This multimodal approach promotes understanding through a variety of sensory inputs and caters to various learning preferences. By considering each individual's interests, learning styles, and abilities, creative content facilitates personalized learning experiences. It may be modified and tailored to fit the diverse needs of learners, increasing inclusivity and accessibility.

Despite the benefits that creative content can offer to learners, there are challenges faced by creators when producing creative content. The biggest challenge is to produce content, which is different, unique, and new, especially in a crowd of saturated content. The creator lacks ideas to create something that stands out from the crowd. Time constraints are also an issue in creating good-quality content, which requires a lot of time beside extra stress to meet deadlines. Capturing and maintaining learners' engagement can also be challenging as creators have to find better ways to ensure learners are engaged well and keep their interest in their learning. Receiving feedback and criticism is part of the process of developing creative content, but sometimes conflicting preferences and range of the preferences can be a challenge.

Creative content enhances learning experience of learners by making it fun, significant, and relevant. It promotes active participation in their own learning, creates important skills, and discovers their unique talents and interests. Creative content accelerates the twenty-first century learning skills — creativity, critical thinking, collaboration, and communication that learners should acquire. Although there are some challenges faced by creators, the benefits that learners gain are far more useful.

6. E-learning modalities

E-learning that is purposed to support adult learners through the open education philosophy is designed with the assumption that adult learners are self-directed. Therefore, self-instructional learning materials (SIM) are often used to deliver content. SIM uses instructional design strategies in delivering content. As such, it differs from a textbook. In the early days, SIM is often published in pdf format using ‘Read’ modalities. Later, SIMs are developed using HTML incorporating sound clips in mp3 offering an additional modality, the ‘Listen’ modalities. As advance video technology enable compression allowing video in byte sizes be played with instantaneous play time, the ‘Watch’ modalities were enabled. RWL modalities are not new. These exist in the past but had been played using the different formats: paper, radio, and television. The internet and ICT technology enabled all three modalities accessed through a single device, a computer, laptop, table, or even a phone. ‘Watch’ mode was further enriched using multimedia, animation, interactivity, and gaming. These enabled developments of creative content that interest learners and ease integration of RWL modalities. The remaining description of e-learning modalities is based on the SIM development from a completed project, the learning spaced developed, and tested in an ongoing project, as well as concepts developed for a future project.

In the development of RWL modalities for the course shown in **Figure 2**, efforts were made in order to describe images in audio format. In creating the audio, it is important to remember mere description of the image is not the aim. The use of images is not merely to fill-in pages but to offer a clear depiction of the concept delivered. The same objective must be used in creating the audio file. The targeted learning outcomes of each modality must be achieved with similar effectiveness and efficiency. UDL principles must be set as criteria in the development of RWL modalities. The extension of RWL to include skill development *via* kinesthetic modality was incorporated through a self-instructional online workshop. The delivery of the online workshop is scheduled to be tested in August 2023. The use of virtual space to enhance the development of RWL-kinesthetic (RWL-K) modalities will be explored.

Assessment is another area of interest. Efforts must be made to offer assessment *via* RWL-K modalities. This is an area will be explored under another project. At present, efforts are placed in creating three different modes of online assessment with differing objectives: (i) Assessment as learning, (ii) Assessment for learning, and (iii) Assessment of learning. Assessment as learning is developed using an interactive yes/no

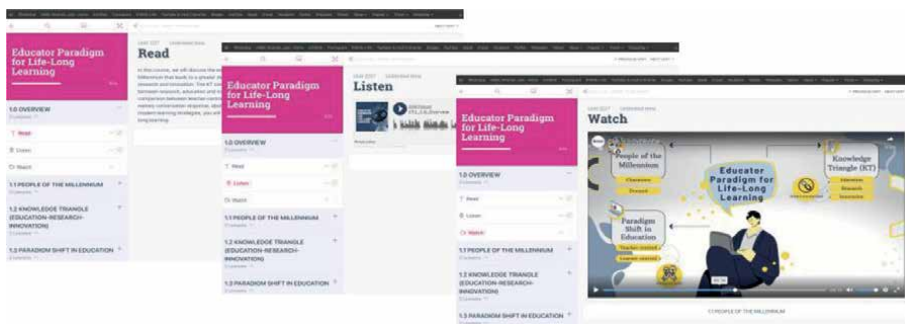


Figure 2. RWL modalities offered via a short course for educators. (Note: The course and the learning space were developed by the authors under a consultancy project).

questions that are suggested as a suitable mode for reinforcing knowledge acquisition. Assessment for learning is explored using authentic pedagogy and portfolio assessment that encourages learners to be creative, critical, collaborative, and communicative (4Cs) *via* indirect/ hidden curriculum strategies. Collaborative learning space is supported *via* an online peer forum. Learners are encouraged to share related experiences from their teaching and learning in the forum. They are also supported *via* additional resources designed to enrich their learning experience and help them to be critical and creative in their efforts to develop the proof of their portfolio. They learn to communicate their learning outcome using suitable templates.

E-learning modalities must undergo continuous improvement to ensure effective and efficient achievement of the targeted learning outcomes. Improvements must include efforts in the creative use of technology in content creation and development of a learning space. Efforts must also be in place to ensure that the role of technology is to ensure access, inclusivity, and quality education *via* effective and efficient achievement of educational outcomes. We ought to take a pause to reflect and improve our understanding of what had happened, the impact of the pandemic on education, and how best to move forward by constructing a post-pandemic education service that projects beyond SDG 4 targets to ensure an educational service that is risk tolerant, inclusive, and adaptable, is able to meet both local and global needs.

7. Conclusion

The COVID-19 pandemic era have several great impacts on us. One is the impact on the education and the dilemma whether to continue the pursue of quality digital education or turn back to business as usual. Perhaps a hybrid is a more practical solution. This leads to exploration of conditions and choices in the post-pandemic era. One condition that must be part of the proposed solution is inclusivity, which is explored through UDL principles. The role of technology in education is revisited and four important roles were identified, namely: (1) Access to quality glocalized education, (2) Inclusive learning environment, (3) Effective and efficient achievement of educational outcomes, and (4) Development of future skills. Creativity has a role in ensuring the use of technology in the development of creative content and learning space that enables a post-pandemic education service that reaches beyond SDG 4 targets and ensures an education service that is risk tolerant, inclusive, adaptable, and able to meet both local and global needs. Past, present, and future research project work and concepts were used to depict ongoing efforts to increase e-learning modalities through continuous improvement to ensure effective and efficient achievement of the targeted learning outcomes.

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Conflict of interest


The authors declare no conflict of interest.

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Hybrid Learning during Post-Pandemic Era: Challenges and Way Forward Nurturing Students' Creativity

Fauziah Sulaiman, Elnetthra Folly Eldy, Yusry Sulaiman, Sitty Nur Syafa Bakri and Siti Nazirah Butai

Abstract

Hybrid learning during post-pandemic-era, challenges and the way forward nurturing students' creativity. This topic reviews how hybrid learning has been established after the COVID-19 era, especially in higher education institutions context. The situation now is that many institutions continue online classes and, at the same time, blend them with face-to-face classes. Many guidelines are established, but how these mechanisms can nurture students' creativity still needs to be explored, especially when we need our students to compete with twenty first-century skills, one of which is to think creatively. Therefore, this topic will dig more into the review of the situation of hybrid learning during the post-pandemic era, particularly in higher education institutions. Additionally, issues like what is the current practice that potentially can nurture students' creativity through technology are also discussed.

Keywords: hybrid learning, post-pandemic, students' creativity, hybrid learning in higher education, nurturing creativity

1. Introduction

The COVID-19 pandemic has profoundly impacted education worldwide [1–4], including the widespread adoption of hybrid learning models [5, 6]. Hybrid or blended learning is any combination of in-person and remote learning, it is not something new [7]. The approach has been implemented for years in education. As schools and universities were forced to close their physical campuses to prevent the spread of the virus, many institutions turned to hybrid learning to continue educating students while ensuring their safety [8, 9]. Singh [10] stated that hybrid learning was well established in some developed countries like the UK and New Zealand and developing countries like India, Saudi Arabia and Malaysia. However, underdeveloped countries need help to optimise the implementation of hybrid learning [10]. During the pandemic, hybrid learning is the only ad hoc mechanism that allows students to continue their studies while minimising the risk of infection by reducing the number of people

in classrooms and allowing students to learn remotely from their homes. The pandemic accelerated the adoption of hybrid learning, as many institutions quickly had to develop and implement these models to adapt to the rapidly changing circumstances.

While hybrid learning offered a way for students to continue their education during the pandemic, it also presented several challenges. Many students faced difficulties accessing technology and reliable internet connections, and some struggled to stay engaged and motivated in a remote learning environment. In addition, teachers and lecturers face challenges adapting their teaching methods and materials to the hybrid learning model. In providing effective support to students who are learning remotely, like situations that happen in higher education institutions [11], where to ensure university and college students acquire the knowledge, skills and competence during the post-pandemic, they need to fully utilise different resources, techniques and methods, as well as explore alternative techniques and resources, to achieve this noble duty. Hybrid teaching and learning is the ultimate answer [11]. Despite these challenges, hybrid learning has proven to be a valuable educational model, offering greater flexibility and resilience than traditional classroom-based instruction; hybrid learning will likely continue to play an essential role in education even after the pandemic subsides, particularly in higher education institutions [12], as it offers a way to blend the benefits of in-person instruction with the flexibility of online learning.

During the post-pandemic era, hybrid learning presents opportunities and challenges for nurturing students' creativity. Challenges such as limited interaction and collaboration, technology limitations and teacher training and support are the major challenges in implementing hybrid learning [13]. A study done by Pavlov et al. [13] explores the problem of online collaboration between teachers and students in English as a foreign language (EFL) classrooms with an empirical focus on video cameras' role in online collaboration. Their study revealed cameras, although contested as a pedagogical tool, should be seen as an important 'proximity tool' that helps foster collaboration by bringing learners and teachers 'closer'. They then did theories of 'collaboration' *via* the social constructivism lens and argue that collaboration as being 'close' echoes in the digital sense with 'being with' and is core for developing an ecology of virtual collaboration. Therefore, students, peers, teachers, etc., should expose to collaboration unlimitedly through interaction. In contrast, hybrid learning can limit the opportunities for students to interact and collaborate with their peers, which is an essential aspect of nurturing creativity. With face-to-face interaction, students may be able to bounce ideas off of one another, engage in brainstorming sessions, and receive feedback on their work.

Another challenge in hybrid learning to nurture students' creativity is the technology limitations, where hybrid learning relies heavily on technology. Unfortunately, not all students, particularly in higher education institutions, have easy access to the Internet and technology, limiting their ability to engage in online learning activities, such as virtual field trips or multimedia projects. Students may also need access to necessary software, hardware or Internet connectivity, particularly in low-income or rural areas. This situation is known as the digital divide and can create inequalities in access to education and opportunities for learning [14]. Students who lack access to the necessary software technology may struggle to participate in online classes or complete assignments, which can negatively affect their academic performance [15, 16], particularly in fostering creativity [17]. To address this issue, some schools and institutions have provided students with laptops or tablets, offered low-cost Internet access or created technology loan programs [18]. Additionally, some institutions have adapted their teaching methods to accommodate students accessing

reliable Internet or technology, such as providing printed materials or recording lectures for offline viewing. However, the digital divide remains a significant challenge for many students and higher education institutions as they strive to ensure that all students have equal access to education and opportunities for learning [19].

Teacher training and support are among the most significant challenges in the survival of hybrid learning in higher education institutions [20]. Teachers may require additional training and support to effectively integrate creative teaching practice [21, 22] into a hybrid learning environment [23]. They may need to learn to use new digital tools and resources to foster creativity, encourage collaboration and provide feedback and assessment in a remote setting [21, 22]. This is important to address a few reasons, including adapting to new pedagogical strategies: hybrid learning requires teachers, lecturers or instructors to adjust their pedagogical approaches to facilitate online and in-person learning [24]. Faculty members need training and support to develop new effective teaching methods in a hybrid learning environment, use these tools effectively and integrate them into their teaching. Using digital tools effectively is crucial in hybrid learning as it relies heavily on digital tools, such as video conferencing software, learning management systems and online collaboration tools. Faculty members need a complete development course to optimise and integrate these tools into their teaching. Other than that, facilitating student engagement through hybrid learning also can be done where it can pose challenges to student engagement and participation. Faculty members need training and support to create engaging, interactive learning experiences that motivate and inspire students. From another perspective, assessing student learning is also crucial, where hybrid learning requires a new method for assessing and evaluating student learning online and in person [8]. Faculty members need training and support to develop assessments that measure student learning in a hybrid learning environment. Addressing technical issues also plays a crucial part in hybrid learning, which can present technical challenges, such as connectivity issues or software malfunctions [25]. Faculty members need training and support to troubleshoot these issues and provide technical assistance to students. Therefore, overall, teacher training and support are essential for the survival and success of hybrid learning in higher education institutions. Faculty members who are well-prepared and well-supported can create effective and engaging learning experiences that help students succeed in a hybrid learning environment.

Along with 4.0IR needs, creativity also plays a significant part in what students need to survive in the real world. Creativity in shorts is the ability to generate new and original ideas, concepts and solutions to problems. It combines existing ideas, knowledge and unique experiences to produce something novel, valuable and useful [22]. Creativity can be expressed in various forms, such as art, music, writing, design, science, engineering and entrepreneurship. It requires a combination of imagination, curiosity, intuition, critical thinking and the willingness to take risks and explore new possibilities. Creativity can also be enhanced through practice, experimentation and collaboration. Therefore, when considering the intersection of 4.0IR, hybrid learning, higher education institutions and creativity, several challenges may arise, like balancing technical skills and creativity within the 4.0IR perspectives, adapting creative pedagogies to online platforms, overcoming technological limitations, collaborative creativity in virtual environments, assessment of creative outputs and finally the faculty development and supports. Therefore, these issues must be addressed to ensure students build resilience when entering the challenging workforce. Addressing these challenges requires a holistic approach considering pedagogical strategies, technological infrastructure, faculty support and assessment methods. In addition,

higher education institutions need to embrace a culture of creativity, adapt teaching practices, provide access to creative tools and resources and create a supportive environment that encourages and celebrates creative exploration in hybrid learning settings aligned with the tenets of 4.0IR.

1.1 Research objectives

The primary research objectives of this paper are as under:

RO1: To study the status of hybrid learning during post-pandemic in HEIs.

RO2: To brief about the challenges of hybrid learning in HEIs to nurture creativity.

RO3: To identify the significant way forward of hybrid learning to nurture creativity in HEIs.

2. Models of hybrid learning

Hybrid learning refers to an educational approach that combines traditional classroom instruction with online or remote learning [8, 26]. In a hybrid learning environment, students typically spend more time learning in a physical classroom with a teacher and other students and some time working independently or in small groups using digital tools and resources. Hybrid learning can take many different forms, depending on the needs and preferences of students and educators. For example, some hybrid models may involve alternating between in-person and remote instruction daily or weekly. In contrast, others may combine synchronous (live) online classes with asynchronous (self-paced) learning activities [8]. In addition, hybrid learning can provide students with greater flexibility and autonomy over their learning experience [8], while offering the benefits of in-person instruction, such as face-to-face interaction with teachers and peers [25]. However, it also requires careful planning and coordination to ensure that all students have access to the necessary technology [27] and support to succeed in both the physical and digital learning environments [28].

Hybrid learning, considered the last resort in distance education in combating the pandemic, where technology and educational applications meet, has become the focus of attention of educators and researchers [29]. Therefore, institutions can adopt several models of hybrid learning, depending on their needs and resources. However, according to Johnson et al. [30], there needs to be more consensus on naming different variations of hybrid learning or online learning, for example, hyflex learning, synchronous online and hybrid elements and asynchronous online and hybrid elements. There are four models of hybrid (and blended) education, as suggested by Christensen et al. (2013) [31], that is., (a) rotation, (b) flex, (c) A La Carte and (d) enriched virtual, and indicated that most the hybrid learning falls under one of these four models.

i. Rotational model

In this model, students rotate between in-person and remote learning on a set schedule. For example, some students may attend classes in person for part of the week, while others attend remotely and then switch roles. This approach allows students to interact face-to-face with teachers and peers while providing flexibility for students needing to attend school remotely.

ii. Flex model

In this model, students can choose between attending classes in person or remotely, depending on their preference or circumstances. Teachers may provide synchronous (live) instruction for in-person and remote students and offer asynchronous (pre-recorded) materials and activities that students can complete independently. According to Christensen et al. [31], flex model includes courses in which the online component is the primary support of student learning. Therefore, flexibility is critical as students move on an ‘individually customised, fluid schedule among learning modalities’.

iii. A la carte model

In this model, students can take some classes in person and remotely, depending on their needs and interests. This approach allows students to customise their learning experience and take advantage of online classes or resources that may not be available in person. Unlike the full-time, a la carte online learning model is not a full-time, onsite traditional classroom experience. Instead, students complete parts of classes a la carte and others face-to-face in a conventional campus setting. The enriched virtual model includes courses in which students must complete in-person sessions and then complete part of the learning experience online [31].

iv. Enriched-virtual model

In this model, students attend classes in person for a portion of the week and engage in online learning for the remainder. The online learning component may include self-paced modules, interactive activities or video lectures, while the in-person component may focus on hands-on activities or group projects. According to Christensen Institute, 2023 [32], an enriched virtual model is a course or subject in which students have required face-to-face learning sessions with their teacher of record and are free to complete their remaining coursework remotely from the face-to-face teacher. Online learning is the backbone of student learning when the students are located remotely. The same person generally serves as both the online and face-to-face teacher. Many enriched virtual programs began as full-time online schools and then developed blended programs to provide students with brick-and-mortar school experiences.

v. Hyflex model

HyFlex combines the terms ‘hybrid’ and ‘flexible’. Hybrid learning refers to learning that integrates complementary face-to-face (synchronous) and online learning (asynchronous) experiences to serve intended learning objectives. In this model, students have the option to attend classes in person or remotely, and teachers provide synchronous instruction for both groups. This approach requires teachers to develop and deliver content for both in-person and remote students simultaneously, which can be challenging but allows for maximum flexibility and customisation for students [33].

However, it is important to note that these models are not mutually exclusive and can be combined to create a hybrid learning approach that works best for each individual, institution and student population.

3. Hybrid-Learning in higher education institutions

The situation of hybrid learning in higher education institutions (HEIs) after the post-pandemic period is still evolving and uncertain [34]. Several factors may impact the future of hybrid learning in higher education. First of all, we need to address student demand. Many students have become accustomed to the flexibility and convenience of hybrid learning during the pandemic and may continue to prefer this mode of learning. Therefore, HEIs must assess student demand and adjust their offerings, according to Singh et al. [35]. Secondly, the technology infrastructure, hybrid learning, requires robust and reliable technology infrastructure, including high-speed Internet, video conferencing software, learning management systems and other digital tools [8]. Therefore, HEIs must invest in and maintain these technologies to support hybrid learning. Other than that, faculty readiness is also counted. Faculty members will need training and support to effectively teach in a hybrid learning environment, including developing new pedagogical strategies, adapting course content for online delivery and using digital tools effectively [35].

Meanwhile, assessment and evaluation in the HEIs will need to develop new methods for assessing and evaluating student learning in a hybrid learning environment, including measuring engagement, participation and achievement in online and in-person contexts [36]. Next, hybrid learning for HEIs may have financial implications, including the cost of technology infrastructure, training and faculty support and physical spaces supporting both online and in-person learning [1]. Overall, the future of hybrid learning in HEIs will depend on various factors, including student demand, technology infrastructure, faculty readiness, assessment and evaluation and financial consideration. Hybrid learning will likely continue to play a significant role in HEIs, but its specific form will depend on each institution's unique needs and characteristics.

4. Nurturing creativity from physical classroom

Creativity is 'the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)' ([37], p. 3). The physical classroom environment can nurture creativity by making classroom settings conducive to it [38], where physical classrooms can provide opportunities for students to engage in hands-on activities, such as experiments, art projects and design challenges. These activities can stimulate creativity by encouraging students to explore new ideas, take risks and experiment with different materials and techniques [39]. Other than that, collaboration can also play a crucial role in nurturing creativity and innovation among students in a physical classroom setting [40]. Physical classrooms can facilitate student collaboration by working together in groups, discussing ideas and providing feedback. This collaboration can stimulate creativity by exposing students to different perspectives and ideas and encouraging them to think critically and creatively [38]. Furthermore, face-to-face interaction between students and teachers or lecturers in a physical classroom can foster a sense of community and engagement. In addition, this interaction can promote creativity by providing students with a supportive and interactive environment, for instance, good creativity, such as behaviour from their teacher to explore their ideas and express their thoughts [41].

Another way to nurture creativity through physical classrooms is through multisensory learning, providing a multisensory learning experience. For example, students can engage with materials and resources through sight, sound, touch and smell. Many teachers have suggestions for creative activities they have tried as warm-ups or quick breaks. For instance, ‘visual riddles’ are simple line drawings with many interpretations and can stimulate divergent thinking. On the other hand, ‘free-writes’ can help students to let go of their internal censor [42]. Combining these multisensory can be used as metaphors to help students bloom their academic information [42]. The structured learning environment also is another factor. Physical classrooms provide a structured learning environment with clear boundaries and routines that can help students to focus and stay on task. This structure can benefit students who struggle with self-directed learning and provide a foundation for creativity to flourish [38].

Overall, physical classrooms can nurture creativity by providing hands-on activities, collaboration, face-to-face interaction, multisensory learning and a structured learning environment that can help to inspire and support creative thinking and expression.

5. Nurturing creativity from hybrid-learning

Despite the successful plan of physical classrooms in nurturing creativity in students, it is necessary to ensure creativity also can be promoted through hybrid learning. This is crucial since many HEIs have established hybrid learning in their courses or programs, particularly post-pandemic [24, 43]. Hybrid learning, sometimes interchangeably word as blended learning, is excellent at improving students’ ability to think creatively but is influenced by their metacognition and must be supported by their capability [43].

In general, there are several ways or models to nurture creativity through hybrid learning, for example, design thinking [44, 45], project-based learning [46–48], arts-based integration [49], inquiry-based learning [50] and gamification and game-based learning [51–53]. Therefore, these will bring more options for teachers and students to choose their learning plans. Flexibility in hybrid learning is essential, as it allows students to learn at their own pace and in their own space. This mechanism benefits students who feel more creative in a comfortable or familiar environment. It also allows students to allocate their time and energy according to their rhythms, which can help indirectly foster creativity [38].

Additionally, digital tools can be essential in how hybrid learning can prompt student creativity. Courses often incorporating digital tools, such as multimedia content and interactive software, made life easier for students and more interesting [54]. These tools can provide students with new ways to express their ideas and creativity, such as creating digital art, animations or videos [55].

Foster creativity from hybrid learning also may be successful with collaboration [56], but it might be a tedious learning process [57]. Hybrid learning can encourage collaboration, cooperation and teamwork through online discussion forums, virtual classrooms and group projects [58]. This collaboration can expose students to diverse perspectives and ideas, which can inspire creativity [59]. From all the factors mentioned above, personalised is also essential in nurturing creativity through hybrid learning, allowing learning experiences tailored to each student’s unique interest

and learning styles. This personalisation can foster creativity by allowing students to explore topics and ideas that interest them and approach learning in ways that work best for them [60].

Finally, access to resources. Hybrid learning provides students access to various digital resources, such as online libraries, research databases and open educational resources. These resources can inspire creativity by exposing students to new ideas, perspectives and information [54]. Overall, hybrid learning can nurture creativity by providing students with the flexibility, digital tools, collaboration, personalization and access to resources they need to explore their ideas, express themselves and approach learning in ways that work best for them.

As for higher education institutions (HEIs) specifically, there are similar ways in which hybrid learning can nurture creativity. These include:

i. Interactive learning factor

Hybrid learning can provide interactive learning opportunities to help students explore their creativity. By integrating digital tools, such as simulations, virtual labs and interactive multimedia content, hybrid learning can provide students with an immersive learning experience that can spark their imagination and creativity.

ii. Multimodal learning

Hybrid learning facilitates multimodal learning, which allows students to engage with course material using multiple senses. This can include watching videos, listening to lecturers, participating in discussions and completing interactive activities. As a result, students can explore different perspectives and develop new insights by engaging with course material in various ways, fostering creativity.

iii. Flexible learning opportunities

Creativity in hybrid learning also can be strengthened by providing students with flexible learning opportunities, which can help to accommodate different learning styles and preferences. Students can learn at their own pace, review materials as needed and engage with course content in ways that work best for them. This flexibility can give students the time and space to explore their creativity and develop unique ideas.

iv. Collaboration

Additionally, collaborative learning in HEIs is a must. Integrating it within hybrid learning can facilitate collaborative learning through online discussion forums, group projects and other activities. By working with others, students can explore different perspectives and ideas, which can stimulate their creativity and help them develop new insights and approaches.

v. Access to resources

Last but not least, as adult students in HEIs, students must always be provided with access to resources. Hybrid learning offers students various digital resources, including online libraries, research databases and open educational resources. These

resources can inspire creativity by exposing students to new ideas, perspectives and information.

Overall, hybrid learning in higher education institutions can promote creativity in students by providing interactive and multimodal learning opportunities, flexible learning options, collaboration learning experiences and access to digital resources that can spark their imagination and help them develop their unique ideas.

6. Challenges to nurture creativity through hybrid learning

It is no doubt that education sectors are facing critical challenges during the pandemic to ensure educational continuity. Many researchers documented a series of findings on how to nurture creativity through hybrid learning and its challenges, for example, unequal opportunity among students to be engaged in class activities [1], inefficient support for online students [11], technical issues with the platform, lack of devices for online learning and unstable Internet connections and sound-related issue's [61], the flexibility of the assessment and evaluation of learning quality, as well as teaching and academic programs [62, 63], students' overall learning experience [64], unclear definition of readiness, preparedness and capabilities in doing online learning among lecturers [65] and also the mental health and psychology of higher education students worldwide, for example, [66, 67]. Therefore, HEIs have developed models to address the issue, like providing laptops, collaborative teaching, online teaching apps, gamification, audio-visual learning, tutorial videos, use of school and personal resources and repetition for mastery.

The main challenge always ahead is the technology requirements. Hybrid learning requires access to technology, including devices and reliable Internet connections, which may be challenging for some students [1]. Social interactions are also crucial in spreading a positive 'web' between peers, teachers and lecturers to promote learning. Therefore, hybrid learning may reduce social interactions and face-to-face communication between students and teachers, which can impact the quality of the learning experience [8]. Additionally, experience e-instructors to assist hybrid learning, as stated by Gulbahar and Kalelioglu [68], could also contribute to successful hybrid learning. E-instructors are instructors who might well be experienced in teaching and learning contexts and possess high technology literacy. Being an experienced instructor with advanced technology skills is necessary but more is needed to lead to an instructor becoming an effective e-instructor.

Typically, a fully face-to-face classroom makes it easy for teachers or lecturers to follow students' assessments or performance. However, it is difficult for some to monitor students' progress through hybrid learning. Hybrid learning may make it difficult for teachers to monitor student progress and provide timely feedback [69]. This situation will worsen when surrounded by unequal access from students. In addition, hybrid learning may exacerbate existing educational inequalities, as students with limited access to technology or support may need to catch up [1].

The next issue revolves around the increased workload for teachers. Hybrid learning can increase the workload for teachers, who must prepare and deliver content for both in-person and remote instruction and provide individualised support to students in both environments [11]. Therefore, these challenges that evolve through hybrid learning may slow the students' creativity and thus need to be addressed appropriately by HEIs. **Figure 1** shows a subset diagram representing how HEIs students' creativity can be nurtured through hybrid learning during the post-pandemic.

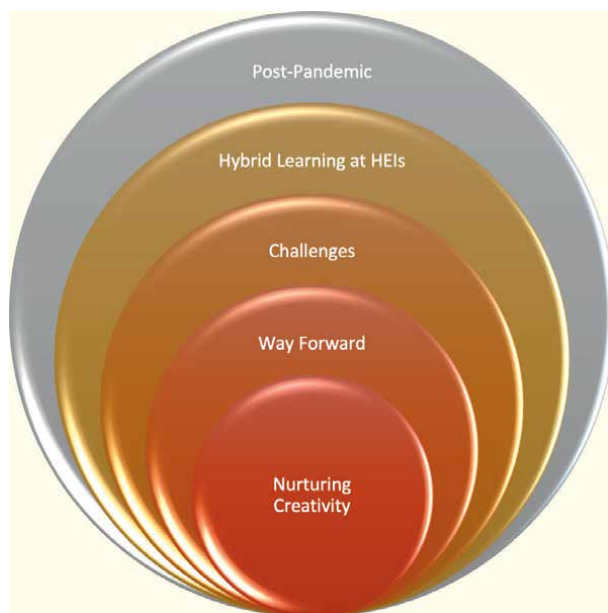


Figure 1.
Nurturing creativity at HEIs during post-pandemic through hybrid learning.

7. Best practices of hybrid learning at HEIs during and post-pandemic

One of the essential practices in a hybrid learning environment is communication. Thus, establishing clear communication channels is no compromise to ensure information lingers effectively between all parties. Therefore, HEIs should strengthen clear communication channels, such as e-mail, discussion forums or messaging apps, to inform students and instructors about course updates, assignments and other important information. HEIs should also ensure that students can access the necessary technology to participate in online coursework, such as laptops, tablets or Internet connectivity. Therefore, providing access to essential technology is critical. HEIs should also provide technical support to students and instructors to address any technical issues.

Undoubtedly, the structure of a course, regardless of its nature, needs special touch by experts. Therefore, HEIs should develop clear expectations for online coursework, including deadlines, requirements and grading policies. Thus, HEIs should create clear expectations for online coursework. This method can help students stay on track and understand what is expected in a hybrid learning environment.

Offering training and support for instructors is another factor in how hybrid learning can be successfully done at HEIs. Everybody is on a panic alert during the first two years of the pandemic. Where we need to turn to the electronic method in a split second, this situation made all stakeholders at HEIs, try to catch up with learning no matter what. Thus, HEIs should provide training and support for instructors to help them develop effective pedagogical strategies and use technology tools effectively in a hybrid learning environment. Fostering student engagement and interaction through hybrid learning can pose challenges for student engagement and interaction. Therefore, institutions should develop strategies to promote student

engagement and interaction, such as virtual office hours, online discussions or group projects.

Create opportunities for community building: hybrid learning can be isolating for students and instructors. Institutions should create opportunities for community building, such as virtual events, social media groups or online clubs. Continuously evaluate and improve the hybrid learning experience: institutions should constantly evaluate and improve the hybrid learning experience based on feedback from students and instructors. Doing this frequently can help identify areas for improvement and ensure that the hybrid learning experience is effective and engaging for everyone involved.

By implementing these best practices, HEIs hope to provide effective and engaging hybrid learning experiences for students and instructors during and post-pandemic.

8. Discussion

There are advantages of implementing hybrid learning in post-pandemic, particularly in nurturing students' creativity. As we all know, the strength of hybrid learning comes from its flexibility. Hybrid learning allows students to learn at their own pace and on their schedule, allowing them to balance work, family and other responsibilities. Students are free to choose models of hybrid learning, for example, rotational model, flex model, ala carte model etc., that fit their daily life activities, considering some students at higher learning institutions are working to continue studying and get a certificate. This will bring much more independent learning and more opportunity for everyone to pursue education anytime and anywhere.

From hybrid learning as well, teachers or lecturers can prepare students' motivation to learn through personalisation. Hybrid learning allows for more personalised learning experiences by providing opportunities for students to work independently and receive individualised support from educators. Usually, during hybrid learning, teachers or lecturers will have more time to assist their student one-to-one, as the teaching and learning process is not necessary for the specific period, like in the face-to-face class. Moreover, students may e-mail or ask their lecturer through a forum in the learning platform, and the teacher or lecturer can respond to the inquiries on their own time. This mechanism is a powerful communication method as it engages the mutual communication between two parties. Therefore, students would feel that there is always someone to rely on when they have learning issues. This method also may increase engagement between peers and teacher or lecturer by offering various learning experiences and opportunities to collaborate with other students. Collaborating with many people and mingling with teaching and learning resources that can give students access to a broader range of resources, including online materials, multimedia content and interactive tools to achieve their learning objectives, indirectly promotes students' creativity.

From here, the future of hybrid learning looks promising, as it offers a flexible and personalised approach to education that can accommodate diverse learning needs and circumstances. There are some potential trends and developments in the future of hybrid learning, such as increased use of technology. As technology evolves and becomes more accessible, hybrid learning is likely to rely even more heavily on digital tools and resources. This could include artificial intelligence, virtual and augmented reality and personalised learning platforms adapting to students' needs

and interests. Other than that, education institutions should look for more options for teaching and learning approaches focusing more on student-centred learning. Hybrid learning emphasises student-centred learning, allowing students to control their learning experiences and pursue topics that interest them more. This approach could become more prevalent as institutions adopt more flexible and personalised educational approaches. Ways of how students-centred learning could promote learning through collaboration and networking. Hybrid learning allows students to collaborate and network more openly with peers from different locations and backgrounds. In the future, institutions may leverage these opportunities to create global learning communities and foster creativity through cross-cultural understanding and collaboration.

Speaking of limitless boundaries where everyone can study anytime and everywhere, it is time to blur the edges. As hybrid learning blurs the boundaries between online and offline learning experiences, institutions may begin to rethink traditional concepts of time and space in education. For example, learning could occur outside of traditional classroom settings and schedules, with students engaging in self-paced or project-based learning that incorporates real-world experiences. Finally, hybrid learning could emphasise students' soft skills. Hybrid learning emphasises developing soft skills such as creativity, collaboration, communication and critical thinking, which employers increasingly value. Institutions may highlight these skills more in the future as they become essential for success in an increasingly complex and interconnected world.

Overall, the future of hybrid learning is likely to be characterised by greater flexibility, personalisation and collaboration as institutions strive to meet learners' evolving needs and expectations in a rapidly changing world.

Therefore, the question of, can students' creativity foster through hybrid learning? There is no exact answer to this. However, creativity undoubtedly can be nurtured among students if the teaching and learning plan and the platform are in their best condition to transfer knowledge and upskills. Therefore, hybrid learning plays an important role and has the potential to nurture students' creativity at higher education institutes. Students' creativity can thrive and even be nurtured through hybrid learning. While hybrid learning may present some challenges to creativity, such as limited in-person interaction and access to physical resources, it also offers unique opportunities for students to explore their creativity and learn in new ways. Therefore, here are some ways that hybrid learning can support and nurture students' creativity. The first one is through digital tools and resources. Hybrid learning provides various digital tools and resources to support and enhance students' creativity. For example, students can use digital art software or video editing tools to create multimedia projects or collaborate with peers using online brainstorming and collaboration tools. Secondly, hybrid learning can be flexible and customisation. Hybrid learning allows students to customise their learning experience and pursue topics that interest them, which can foster creativity and motivation. Students can also work independently and on their schedules, providing more time and space for creative thinking and exploration.

The third way hybrid learning can foster creativity among students is through project-based learning. Hybrid learning can support project-based learning, which allows students to work on real-world projects and apply their creativity to solve problems and create solutions. The project can be designed to be completed online and in person, allowing for individual and collaborative work. Last but not least, hybrid learning can promote creativity through peer collaboration and feedback.

Hybrid knowledge will enable students to collaborate and receive feedback from peers and instructors in both in-person and online settings, which can foster creativity and provide new perspectives on projects and ideas.

While hybrid learning may present some challenges to creativity, it also offers unique opportunities for students to explore their creativity and learn in new ways. With the right tools and support, students can contribute to developing their creativity and imagination in a hybrid learning environment.

Therefore, the way forward of hybrid learning during the post-pandemic era is auspicious. Higher learning institutions can consider these plans to promote students' creativity through hybrid learning. Teachers or lecturers can always use collaborative tools such as virtual whiteboards, chat rooms and video conferencing to facilitate student communication and collaboration. They can also encourage using social media and other online platforms to promote students' collaboration and networking.

Additionally, blending online and offline activities also help students more effectively catch up with their work. For example, teachers and lecturers can design hybrid learning experiences incorporating online and offline activities, such as virtual field trips and in-person discussion and reflection. This approach can help bridge the gap between online and offline learning experiences and promote creativity indirectly.

Personalised learning can also promote creativity under a hybrid learning setup. Teachers and lecturers can personalise learning experiences for students, considering their unique interests, skills and backgrounds. This approach can foster creativity by allowing students to explore topics of particular interest and pursue projects that align with their passions. Last but not least, professional development and support also must be considered to ensure the plan of promoting students' creativity through hybrid learning is a successful plan. Teachers or lecturers can receive professional development and support to help them integrate creative teaching practices into a hybrid learning environment. This can include workshops, mentorship programs and ongoing coaching to help them build their skills and confidence in using new digital tools and resources.

9. Conclusions

In conclusion, nurturing higher education institution students' creativity through hybrid learning is more challenging than it may seem, particularly during the post-pandemic era. Therefore, everyone needs help finding what or how is the best way to convey knowledge and promote learning optimally. In this paper, it was discussed the status and situation of hybrid learning during post-pandemic in HEIs. The paper is also concerned with the challenges of hybrid learning in HEIs to nurture creativity. And finally identified the significant way forward of hybrid learning to nurture creativity in HEIs. Through several experiences worldwide, it can be said that encouraging students' creativity from the cutting-edge plan of learning, such as hybrid learning, needs more collaboration from parties, for example, teachers, lecturers, administrators, policymakers and last but not least, the student. It is hope and creativity that foster through hybrid learning in the HEIs can fulfil the needs of the Fourth Industrial Revolution in education by providing students with the digital literacy skills, personalised knowledge, flexibility, collaboration and lifelong learning skills needed to succeed in the twenty first century.

Conflict of interest

The authors declare no conflict of interest.

Notes/thanks/other declarations

Place any other declarations, such as ‘Notes’, ‘Thanks’, etc., before the references section. Assign the appropriate heading.

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Section 6

Emerging Workforce Trends

Perspectives Regarding the Improvement of the Professional Training of Employees in Public Institutions

Dragos Valentin Dinca and Catalina Fotache

Abstract

In recent years, public institutions have been faced with a new challenge in the field of professional development of employees: adaptation to the pandemic context and the use of distance learning technologies. This chapter aims to analyze the ways of conducting learning activities in public institutions in the last three years, to identify future training needs and the availability of integration of new technologies. In order to achieve this purpose, the literature from the past three years was reviewed and a study was conducted targeting five public institutions in Romania. The instrument used was the questionnaire, which included qualitative elements to allow the classification of the statistical results. Despite the pandemic context, the analyzed public institutions carried out training activities for employees, but with a classic approach in terms of organization and the topics of the training. The analysis targeted public institutions in Romania; being carried out from the perspective of the specific legal framework, the results may not be multiplied or applied to other administrative systems. The study provides evidence of the degree of change in public organizations, changes generated by a pandemic crisis. Furthermore, it classifies these changes in a recognized theoretical model.

Keywords: public, institutions, training, training needs, new technologies

1. Introduction

The mission of public institutions is to carry out activities of general interest, that is, public services. This goal cannot be achieved without competent, well-trained people, devoted to the public welfare, who understand the importance of constantly improving their level of professional knowledge. Thus, administrative performance is dependent on the skills and professional training of employees in public institutions.

In this context, states have regulated the institutional and procedural system and the financing mechanisms through which their own employees have access to different forms of professional training. Moreover, in some administrative systems, the improvement of professional training represents an obligation of the employees,

which corresponds to the right of the institution to establish plans and programs for professional training and improvement. Sometimes career development is conditioned by the completion of certain forms of training.

In European countries, according to the applicable legislation, institutions are appointed to manage the entire process or certain components thereof: The Civil Service Division in Austria, Federal Academy of Public Administration in Brühl, Germany, The Civil Service Section of The Ministry of the Interior, Czech Republic, Directorate General for Qualification of Employees in Public Functions—Portugal, Public Sector Directorate in Slovenia.

The topic of training and improving the professional training of employees in public institutions is a common subject for European administrations. In one form or the other, it exists in every administrative system. However, the last years, marked by the pandemic context and, more recently, the East-European armed conflict, have seen changes in how training activities are organized. Certain Eastern European states, and implicitly their public institutions, are going through a financial crisis that leads to the reduction of expenses, and implicitly of the resources allocated to professional training.

The literature of the last three years has focused on the subject of professional training and improvement of public administration employees from various perspectives, such as:

- Training from the perspective of correlation with sustainable development objectives [1] or sustainability as a learning subject and correlation of the training process with the sustainability criteria [2];
- Digitization of public administration as a reform [3, 4], impact on public systems [5], but also increasing the digital skills of employees [6];
- The impact of the Sars-Cov-2 pandemic on public administration, its components [7], and training processes [8–10];
- European models of training in public administration [11], the training content [12, 13], or the evolution of training systems [14];
- Training in the online system for public administration, as a combination of two other topics: digitization and the health crisis [6, 15–17].

2. Methodology

This article aims at examining the improvement of professional training in public administration in the recent years from the perspective of accessibility, organization, and training topics.

The second objective is to identify the existing perspectives regarding the professional training of employees in public institutions, starting from the experience of the past few years.

To achieve the two objectives, a questionnaire (see Appendix) on institutional capacity was applied to the employees of five Romanian public institutions. It included five questions that were answered between October 2022 and April 2023 (see **Table 1**).

The first question was aimed at identifying the percentage of respondents who attended long- or short-term courses in the last couple of years. Those who attended

No.	Institution	Number of questionnaires	Number of employees	Percentage of respondents of total employees
1	County Counsel of Hunedoara	35	155	22.5%
2	Municipality of Adjud	31	145	21.5%
3	Municipality of Onești	55	240	22.9%
4	District 1 of Bucharest Municipality	105	424	24.7%
5	City of Odobesti	41	165	24.8%

Table 1.
The institutions that responded to the questionnaire.

such courses were asked to indicate the themes, having available a predefined list (as well as the “others” option).

It was also requested to indicate from a predefined list the preferred training tools in the future.

The last open question targeted the training planning tools needed at the level of their institution.

The questionnaire included elements aimed at identifying the target group: gender, level of education, seniority in administration, level of the position (management/operating staff), and the type of institution in which the respondents carry out their activity.

The data were collected with the help of a platform designed for creating questionnaires. The platform centralized the data and generated the graphs.

From the point of view of the theoretical model used, Dunphy and Stace proposed a model [18, 19], which underlined the fact that organizations should vary their change strategies according to the environmental changes in order to achieve an “optimal match.” Depending on the environment, both the managers and the agents of change should vary their change strategies. The model proposed focuses on the environmental factors, as well as on the management forces, which play a crucial role in any process of change.

Thus, according to the mode proposed, change can be classified into four different types: finetuning, modular transformation, incremental adjustment, and corporate transformation. Both authors considered that change should not occur only on incremental basis but it can also occur on radical or discontinuous basis. They equally emphasized that transformational change could be both consultative and coercive in nature.

3. The legislative and institutional framework for the improvement of the professional training of Romanian public administration personnel

Law no. 53/2003 on the Labor Code [20] establishes the employer’s obligation to ensure regular access of employees to professional training. In accordance with the provisions of art. 191 of Law no. 53/2003 as subsequently amended and

supplemented, “the professional training of contractual personnel is carried out based on the annual plan for professional training developed by the employer, in consultation with the trade union or, as the case may be, the representatives of the employees.” Individualized professional training is established, according to art. 192 of Law no. 53/2003, by the employer together with the employee in question, considering the criteria considered in the annual plan for professional training and the conditions under which the activity is carried out at the workplace.

Regarding civil servants, Emergency Ordinance no. 57/2019 [21] on the Administrative Code as subsequently amended and supplemented specifies in para. (1), art. 458 and art. 459 that “public servants have the right and obligation to continuously improve their skills and professional training.” This right of civil servants corresponds to the obligation of the state and local communities to create the legal and institutional framework and to ensure the resources necessary for its implementation, as also noted in art. 459 of the Administrative Code, which refers to the obligation of public authorities and institutions to annually prepare the professional development plan for civil servants. The obligation of civil servants to improve their professional training arises from the fact that they exercise privileges of public power, and their actions are subject to general interest. In this context, the civil servant must follow forms of training organized at the initiative or in the interest of the public institution. Also, according to the Administrative Code, public authorities and institutions have the obligation to communicate to the National Agency of Civil Servants the data requested concerning the training and improvement of civil servants.

According to art. 16 et seq. of G.D. 1066/2008 [22], “in order to ensure compliance with the right and fulfillment of the obligation of continuous improvement of skills and professional training, every year, when assessing the individual professional performances, the areas in which the assessed civil servant requires additional professional training in the following period are identified in the assessment report.” Moreover, the identified professional training needs are supplemented, if necessary, with the professional training needs resulting from legislative changes in the civil servant’s areas of expertise, as well as from any relevant changes in the job description.

According to art. 5 [22], professional training is carried out in the following manners:

- “Training programs organized and carried out by professional training providers, completed with a certificate of attendance or, as the case may be, a graduation diploma;
- Training programs organized and carried out or, as the case may be, approved by employers within public authorities and institutions;
- Training programs organized and carried out within the implementation of projects with external funding;
- Other forms of professional training provided by the applicable law.”

According to Order no. 762/2015 of the President of the National Agency of Civil Servants [23], for establishing the priority areas in which professional training programs for the public administration are organized, the following priority areas are provided:

- a. Management of public and public utility services;
- b. Public policies and strategic planning;
- c. The internal/managerial control system in public entities;
- d. Human resources management;
- e. Financial-budgetary and assets management;
- f. Fundamental human rights and freedoms;
- g. The right to public integrity and anti-corruption policies;
- h. European Union legislation;
- i. Communication, public relations, decision-making transparency, information—public/classified/personal data;
- j. Civil procedure and contentious administrative matters.

The Romanian institutional system for the improvement of the professional training of employees from public institutions includes the National Institute of Administration, the National Agency of Public Servants, and the National Authority for Qualifications. Each public institution appoints a person in charge of professional training, allocates financial resources *via* the annual budget, and develops an annual professional training plan. Usually, the improvement of professional training is achieved through courses of 2–5 days, held outside the institution.

4. Improving professional training in Romanian public institutions

The first question attempted to identify the percentage of respondents who attended long- or short-term courses in the past three years, that is, 2020, 2021, and 2022, a period marked by the restrictions imposed by the Sars-Cov2 pandemic (see **Figure 1**).

Despite travel restrictions (see **Figure 1**), significant percentages of employees participated in training activities (56.5% in District 1, Bucharest and 51.06% in Adjud), which lead to the conclusion that online courses were accessed and there is availability for such a format. On the other hand, the locality with the lowest budget also had the lowest participation rate (13.5% Odobesti).

Those who participated in various forms of training/improvement programs indicated the topics of these courses (question no. 2, see Appendix) (see **Figure 2**).

In the municipality of Adjud (see **Figure 2**), it can be observed, on the one hand, that the topics of the courses mainly focused on decision-making transparency and the management of the public function, and on the other hand, that the employees did not attend, in the recent years, courses in areas with a major impact on the organization and operation of the institution. Furthermore, the courses aimed at the principles, concepts, and basic elements of public administration were attended by a very small number of employees. It is noted that no courses were attended in the

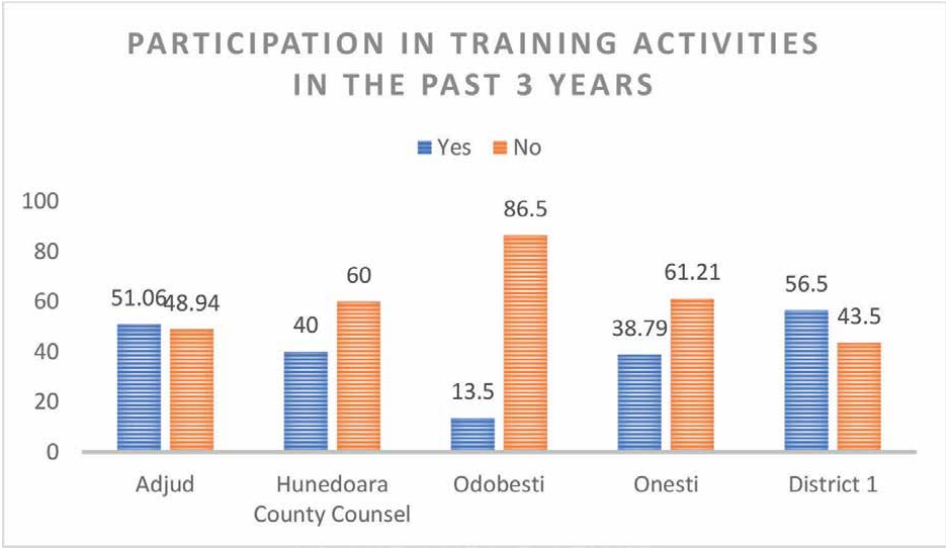


Figure 1.
Percentage of participation in training activities in the last 3 years.

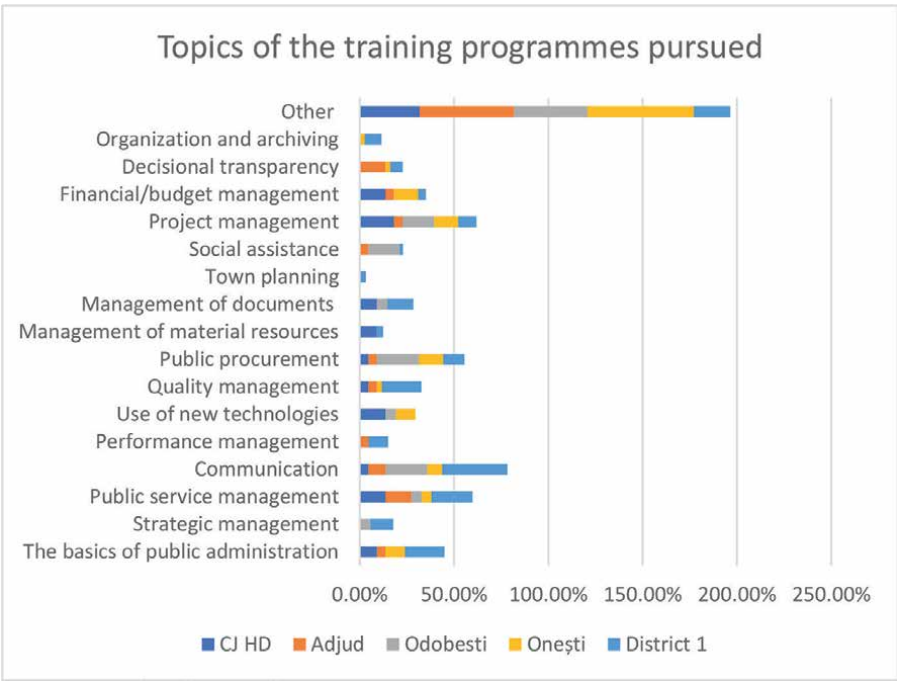


Figure 2.
The topics of the courses attended.

field of strategic planning, local public policies, and the internal managerial control system. This aspect reverberates on the availability of human resources with skills in the field of strategic planning and local development. Another vulnerability is that no courses on the use of new technologies have been organized, which is detrimental to innovation processes.

In the county of Hunedoara (**Figure 2**), courses that have a general nature (communication, basics of public administration, etc.) have, overall, a higher ranking than the specific ones. The courses for which respondents did not indicate any answer are strategic management, performance management, use of new technologies, quality management, town planning, decision-making transparency, and organization and archiving.

In the last three years, the employees of the Odobești city hall (**Figure 2**), have not attended any training course in areas with a major impact on the organization and operation of the institution, nor did the employees focus on courses aimed at the principles, concepts, and basic elements of public administration, for their professional training.

In the case of the municipality of Onești and District 1 (**Figure 2**), it can be noted that courses of a general nature (communication, basics of public administration, etc.) have, overall, a higher ranking than the specific ones. Furthermore, there are certain courses for which the respondents did not indicate an answer, namely: use of new technologies.

The third topic of analysis concerned the training tools preferred by respondents for future training activities (**Figure 3**).

With regard to the training tools preferred by respondents (see **Figure 3**), the respondents' preference toward classic training methods (practical applications, case studies, presentations, or teamwork) can be observed, while nonformal training methods, more modern, and complex, such as group discussions and brainstorming, are not among the respondents' first preferences.

It is found that “role-playing” represents a method that, from the perspective of the analyses, is particularly effective in transmitting certain skills, being one of the most active learning methods; however, it is not found among the respondents' preferences (the fewest mentions).

Furthermore, although there was the option of an open answer, learning channels such as informal coaching, mentorship, regular rotation, project assignments/tasks,

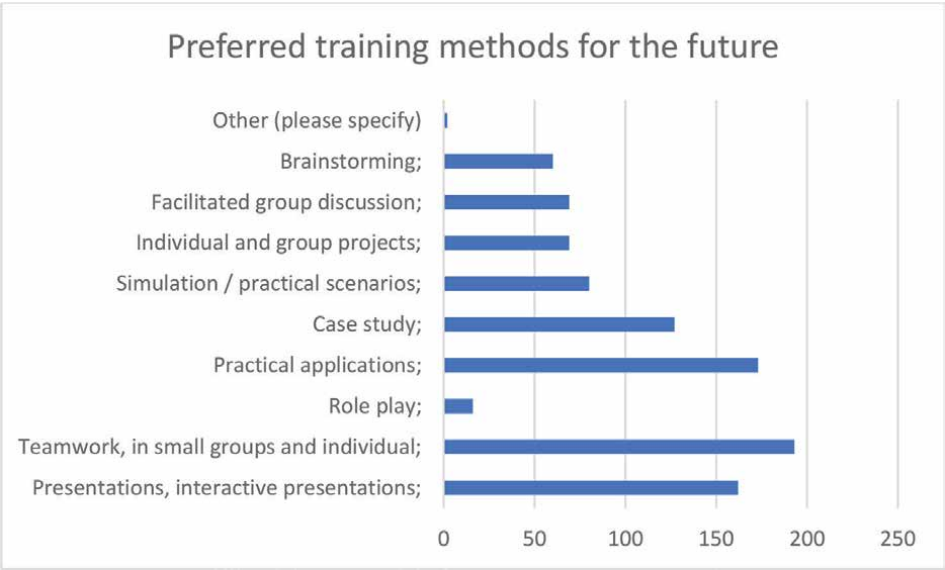


Figure 3.
Preferred training methods in the future.

and 360-degree feedback considered by specialty studies as highly efficient, were not mentioned by the respondents, from where we can infer that the respondents do not have information, and/or have not benefited from training courses through modern teaching-learning methods.

Regarding the fields of training needed in the future (see **Figure 4**), the answers demonstrate, interestingly, a preference toward the strategic field, at the expense of the operational field. Among the training topics indicated by the respondents are: leadership, strategic planning, integrity management in public administration, risk management, CAF (self-assessment framework for the operation of public institutions), strategic management—balanced scorecard, development of operational and system procedures, decision-making transparency and confidentiality, development and implementation of public policies, decision-making practices in public administration, communication/moderation of debates, planning and carrying out activities, and business analysis in the public sector.

The last open question (see Appendix) considered the training planning tools needed at the institutional level. It was found that no institution has developed the



Figure 4.
Training topics needed in the future.

common/usual set of documents to guide the conduct of activities. Thus, the following documents are *missing*:

- Procedure for professional training or an integrative human resources policy, only a professional training plan being in place;
- Annual analysis of training needs, but especially its correlation with budget resources (although the training plan is drafted, the needs identified and included most often are not supported by budget allocations within the institution).

Regarding the preparation of the professional development plan for civil servants, the entity must refer to the Order of the President of the National Agency of Civil Servants no. 233/21.03.2022 [24] for the approval of the content and instructions for the preparation of the professional development plan for civil servants, as well as the manner of communicating the data requested by the National Agency of Civil Servants regarding the professional development of civil servants.

5. Conclusions

Although during the period under review, the travel restrictions generated by the pandemic context were in place, and an important percentage of employees of the targeted public institutions attended professional training development activities, reaching up to 56.5% (see **Figure 1**) of the total number of employees, which shows compliance with the legal framework in Romania on the obligation to improve the level of knowledge for civil servants.

However, in three of the examined institutions, the percentages are below 50% (see **Figure 1**). The training percentage is very low, considering on the one hand the legal training obligations, and on the other hand, the lifelong learning policies, promoted at the level of the European Union and, last but not least, the free training opportunities initiated by certain institutions, such as the National Institute of Administration and the National Agency of Public Servants, in certain projects carried out at the institutional level.

Topics of the courses attended have a general nature, with no major impact on the organization and operation of the public institutions. At the level of the five institutions, no courses on the use of new technologies were organized, which is detrimental to innovation processes, and no courses were attended in the field of strategic planning, local public policies, and the internal managerial control system. This aspect has further consequences on the availability of human resources with skills in the field of strategic planning and local development.

Among the training topics indicated by the respondents for the future are: leadership, strategic planning, integrity management in public administration, risk management, CAF (Self-Assessment framework for the operation of public institutions), strategic management—balanced scorecard, development of operational and system procedures, decision-making transparency and confidentiality, development and implementation of public policies, decision-making practices in public administration, communication/moderation of debates, planning and carrying out activities, and business analysis in the public sector.

Public institutions must plan their professional training activities and develop internal procedures and multi-annual training plans based on analyses of training needs.

Information technology must represent an institutional priority both from the perspective of the need to use new technologies and innovation, and also from the perspective of moving training activities into the online environment. This is also justified by the fact that, by reference to Dumphy's and Stace's model, the changes within public institutions generated by the Sars-Cov 2 pandemic are of transformational type, in crises, rapid changes being needed to ensure the survival and continuity of the organization. A big part of these changes refers to introducing new technologies and working manners, interaction both within and outside the public organizations.

Conflict of interest

"The authors declare no conflict of interest."

Appendix

Questionnaire

1. Have you attended long or short-term training programs in the last 3 years?
YES [] NO [].

2. If yes, what topic did the attended training program have:

The basics of public administration	Yes
Strategic management	
Public service management	
Communication	
Performance management	
Use of new technologies	
Quality management	
Public procurement	
Management of material resources	
Management of documents	
Town planning	
Social assistance	
Project management	
Financial/budget management	
Decisional transparency	
Organization and archiving	
Other	

3. What training methods/tools do you prefer in the future?

Presentations, interactive presentations;	Yes
Teamwork, in small groups and individually;	
Role play;	
Practical applications;	
Case study;	
Simulation/practical scenarios;	
Individual and group projects;	
Facilitated group discussion;	
Brainstorming;	
Other (please specify)	

4. Please select the training topics that you consider useful for the future:

	To a very small extent	To a small extent	To a large extent	To a very large extent	I do not know/I do not answer
Leadership					
Strategic planning					
Integrity management in public administration					
Risk management					
CAF (Self-Assessment Framework for the Operation of Public Institutions)					
Strategic management—balanced scorecard					
Development of operational and system procedures					
Decision-making transparency and confidentiality					
Development and implementation of public policies					
Decision-making practices in public administration					
Communication/moderation of debates					
Planning and carrying out activities					
Business analysis in the public sector					


5. What are the existing training planning tools at the level of your institution?

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German SMEs and “Home Office”: Narrative-Driven Game-Based Awareness Raising with Long-Term Efficacy

Margit C. Scholl

Abstract

The COVID-19 pandemic triggered a large, sustained shift to working from home. This sudden shift to a new environment rapidly increased the opportunities for cyberattacks on individuals. The employees of small- and medium-sized companies can be seen as a major new target for cyberattacks because cybercrime prevention is often neglected in home offices. Human beings are the current target of cyberattacks as well as the last line of defense, especially when technology fails. Awareness of cyber situations is an essential aspect of managing information security risks. Continuous information security awareness measures targeted to all employees are an existential necessity for companies if they are to develop their digitization successfully. The article illustrates a German project developing an overall scenario with a mix of measures for companies designed to raise such awareness. Analog and digital narrative serious games with interactive and discursive elements focused on the home office are described in detail as a part of the overall scenario. They must be carefully designed and used within a practice-oriented mix for the target groups, so that information security is made tangible and comprehensible. All materials will be made available for noncommercial use in German on the project website by September 2023.

Keywords: information security, data protection, cyberattacks, raising awareness, game-based learning, serious games, analog and digital storytelling, interactive and discursive settings, small and medium-sized enterprises, home office, working from home, cyber risks

1. Introduction

Cybersecurity Ventures predicts that by 2025, the global cost of cybercrime will be USD 10.5 trillion [1]. While we protect ourselves and our valuables in the analog world with various measures in response to very different risks, the same cannot be said of the digital world—there, we are much more casual in how we deal with our personal data. Dukes explains that beyond our current security culture, we need to establish the use of technology and a new way of thinking about it to protect ourselves within anonymous

cyberspace with data transfers within seconds [2]. According to Sample, Loss, Justice et al., sales of Internet-enabled home electronics have increased, with an Internet of Things (IoT) forecast from Gartner in 2017 of well over 20 billion for 2020, allowing many home users to unknowingly become accomplices in cyberattacks [3]. In a survey on security concerns surrounding IoT devices, 99 percent of respondents expressed concerns about data security [4]. However, the chip shortage continues to slow the IoT market recovery, which is why the number of global IoT connections grew by just 8 percent in 2021 to “only” 12.2 billion active endpoints [5]. IoT devices such as thermostats, smart TVs, and household appliances offer attractive access to uninvited guests like attackers. Most users (citizens) are unaware of the basic security settings on their Wireless Access Point or firewall settings provided by their Internet Service Provider and do not know how to change these settings [3]. We must, therefore, all raise our awareness of the risky cyber situation and review and adapt our behavior. This paper seeks to help raise awareness of information security (IS) and data protection (DP) so as to contribute to an overall increase in security culture in Germany, with a special focus on employees in small and medium-sized enterprises (SMEs).

Owing to the COVID-19 pandemic, many companies suddenly had to allow employees to work from home (WFH) [6]. For example, prior to the COVID pandemic, approximately 29 percent of Americans were working from home, while that number has virtually doubled to approximately 60 percent as of April 2020 [7]. The home office (HO) has become a very real experience for a large part of the population due to the pandemic: this is also the case in Germany with lockdowns in business, society, and schools. Practice in Germany shows that the legal basis has not yet been properly prepared [8]. What is certain is that the number of home users has increased very rapidly, ranging from desktop computers and laptops to tablets, smartphones, and devices connected to IoT, and the age groups of users have also increased from adults to children and seniors [9]. At the same time, the shift to remote IT solutions has opened up a plethora of opportunities for cyber incidents and attacks, with the “most popular” now appearing to be phishing schemes and ransomware attacks [10]. This reveals the need for greater cyber awareness and greater competence among the entire population, which also requires a rethink in politics [3]. Fadinger & Schymik examine the effects of HO/WFH: on the one hand, the risk of infection in German regions and, on the other, the output for the German economy [11]. They note that the infection rate has been well contained by HO/WFH and therefore recommend that working from home be maintained for as long as possible so that those workers who cannot work from home can return to work while minimizing the risk of infection [11]. However, this only covers the safety aspect, and it is important to also consider the security side of the story: Fichtenkamm et al. even go so far as to say that “the COVID-19 crisis [has] triggered a cyber pandemic” [12].

The average cost of a data breach has risen to USD 4.24 million, yet many business owners still believe it is unlikely their organization will be targeted [12]. However, nowadays, it is no longer a question of IF a company will become a victim, but only WHEN [13]. Some organizations were well prepared for the COVID-19 pandemic and only had to expand their remote infrastructure, while others had to build digitization from scratch [7]. Because the move to digital was sudden, most businesses, especially small ones, have not had the time to adequately assess their cybersecurity (CS) requirements for HO/WFH [6]. The fact that employees access sensitive corporate data from external networks opens the door to many CS risks that can lead to data loss, data breaches, and, thus, enormous financial losses [6]. Accordingly, the number of security breaches and damage costs reached a record high in 2021, with an average

cost per incident of USD 5.4 million in Canada [14]. Therefore, despite (technical) security measures and risk management guidelines, HO/WFH regulations and employee behavior are reported as important factors affecting CS [14]. The most recent Ponemon Institute survey shows that 71 percent of organizations are very concerned that remote workers put them at risk of data breaches and security vulnerabilities [9]. In addition to cybersecurity risks, data protection risks are also a general concern for members of the public, as their private information is often collected and used [9]. Thus, in general, the cybersecurity behavior of citizens must be made more coherent, which requires a rethink at the government [9] and business levels.

According to Machado & Gouveia, Google’s official blog reports that more than 240 million spam messages containing the word COVID in their text were sent daily and led users to the 42,000 websites created from early to late March 2020 to collect their data illegally [15]. Owing to a general lack of expertise among members of the public, this combined social engineering (SE) technique is successful in 80 percent of the scams used. To experts, these attacks have occurred with great frequency in Latin American countries, especially in Brazil, which saw an increase of around 350 percent in the first quarter of 2020 [15]. The German economy is also affected by a wide range of attacks, and here, too, these are shifting into digital space, while analog forms of attack are decreasing [13]. In 2017, a total of 53 percent of the German companies surveyed were affected, and an additional 26 percent were probably affected; in 2021, the figures were 88 percent and 12 percent, respectively, and in 2022, 84 percent and 9 percent—at the top of the list of data thefts in German companies are communication data such as emails and customer data [13]. Forty-five percent of the companies surveyed by the German Bitkom e.V. in 2022 see cyberattacks as a threat to their existence, while a year earlier, it was only 9 percent [13]. In addition, critical infrastructures continue to be the focus of cyberattacks, and in 2022, the most common types of damage were password theft and phishing attacks [13]. An increase in ransomware attacks is seen as the top cyber threat over this year, 2023, with worrying trends such as “dual blackmail tactics” [16]. In 2022, every second German company was targeted by SE attacks, most commonly via telephone (38 percent) and email (34 percent) [13]. SE can still be found clearly in the private sphere (13 percent) and in professional networks (9 percent); this is followed by private social networks with 5 percent, video conferences with 4 percent, and trade fairs or events with 3 percent [13]. Hackers do not attack the systems first, but in nine out of 10 attacks they start with the employees because they represent the more lucrative end of the business to loot [17]. The attacks on the economy are becoming more professional—in other words, organized crime has increased significantly in 2022 and stands at 51 percent [13].

The introduction shows that the central importance of IS and DP must be given more importance in the future, and this also applies to the area of HO/WFH. The proportion of investments in IT security measured against the total IT budget of the company is growing but is only 9 percent on average for all the companies surveyed [13].

According to the German Chamber of Industry and Commerce (DIHK) survey on digitization, German companies have recognized the wide range of cyberattacks and taken technical precautions [18]. However, their awareness raising and training for managers and employees are weak [18]. This contradiction shows an evident lack of sustained implementation of awareness-raising measures in SMEs. Moreover, Proofpoint’s 2022 phishing situation report notes a general decline in security awareness, suggests pandemic fatigue with an impact on employees’ motivation and attention, and shows a lower priority of security awareness training in 2021 [19].

The research question of this article is as follows: How can we increase knowledge and raise information security awareness (ISA) and cybersecurity awareness (CSA) relating to HO/WFH and adapt human behavior accordingly? Measures that have been tried and tested in practice must be taken into account. For example, the finding from the study by Johansson et al.: Chief Information Security Officers (CISOs) recognized increased awareness among employees when microlearning with shorter topic modules was used [20].

This paper continues as follows: Section 2 summarizes the main findings from literature reviews. In the third section, our complex project is explained, briefly introducing the conceptual background and the story concept, describing preliminary versions of our learning scenarios relating to HO/WFH, and presenting in more detail the development of analog and digital serious games designed to raise awareness in German SMEs. Section 4 focuses on the discussion of the project's results in light of the applied scientific literature, including current evaluation results of the learning scenarios, and the fifth section looks ahead to the next phases of the project. At the end, in Section 6, the contribution of this paper and avenues for future research are summarized.

2. Literature review about information security and data protection in home office

The COVID-19 pandemic has accelerated digitization in all countries. Škiljić assumes differences in how CS is observed in European countries. Croatia is given as an example, which unfortunately was completely silent on the CS threats caused by the pandemic: it simply left its companies to their own devices. Also, it failed to warn individuals [10]. Nyikes sees it as the responsibility of the government and authorities to ensure the CS of Internet users by obliging information and communication technology (ICT) service providers to offer fundamentally secure services (possibly at an additional cost) [21]. The “security awareness and digital competence” of users are important, but according to [21], ICT must relieve users of security burdens and ensure IT security. Bispham et al. point out that while a focus on the threats or increasing security issues associated with HO/WFH is important, it is too narrow. In their opinion, further research is needed with selected case studies involving defined groups of people on the question of whether CS has changed from a barrier to an enabler for remote work [22]. According to Nyikes, the security measures can be divided into four different groups: first, physical (e.g., guarding the premises, visitor treatment, fire protection); second, administrative (e.g., risk analysis, regulation, and business documentation); third, personal protection (the selection of suitable people to trust, security awareness); and fourth, electronic IS (system monitoring, operation, transmission path protection, border protection) [21].

CS—as part of IS—is the backbone of successful digitization of society, and awareness of cyber situations is an essential aspect of managing them [23]. The research conducted by Andreasson et al. in Swedish authorities shows that at the beginning of the pandemic, employee communications focused more on first-order risks such as video conferencing and teleworking than on second-order risks such as billing fraud or SE; it points out that almost two-thirds of managing authorities have not implemented their CS policies but merely initiated or documented them [23]. The emergency situation caused by the COVID-19 pandemic has reorganized the working

world and the educational and social realms; digital education and social communication on the Internet have increased significantly [21]. This increased and sudden use of the Internet has dramatically increased the vulnerability of users and systems [21]. There can be no doubt that there is a link between the COVID-19 pandemic and the increase in cyberattacks on vulnerable sectors, with healthcare organizations being one of the main victims of cyberattacks during the pandemic. This is also the new normal, with the expectation of HO/WFH being increasingly exploited [24].

De Kimpe et al. examine the perceptions of Internet users and show that they are more inclined to take protective measures when they believe that cybercrime poses a more critically serious risk (with a high level of perceived severity) [25]. Machado & Gouveia show that the increase in cybercrime particularly affects those whose expertise and technological knowledge are not in sync with the reality of this threat [15]. Recent research works with strategic game models to defend against Advanced Persistent Threats—here, the timing of the attack and defense movements plays a central role [26]. According to Sample et al., the labor shortage affects all areas of CS, is exacerbated by the growth of IoT, and underpins the need to bolster staff development initiatives to foster more awareness of CS and, more generally, of IS and DP [3]. However, CS also needs people with different perspectives, approaches, mindsets, and methods to solve current and emerging cyber challenges [3]. Sample & Justice further argue that academic silos of disciplines such as law, psychology, sociology, resilience, reliability, statistics, data science, international studies, and others are to be broken down and become increasingly intertwined with CS [27]. Cross-disciplinary team-building and exchange formats are therefore necessary.

Agrafiotist et al. argue that although extensive research has been done to understand the impact of cyber incidents, a model that can support analytics to detect, measure, predict, and prioritize cyber damage is lacking [28]. The cyberattack threat landscape is rapidly changing, and the potential impact of such attacks is uncertain due to the lack of effective metrics, tools, and frameworks to understand and assess the damage businesses are exposed to from cyberattacks [28]. As a result of extensive literature research, the authors create a taxonomy of cyber damage to which companies are exposed [28]. This taxonomy encompasses five broad themes: physical or digital damage, economic damage, psychological harm, damage to reputation, and social and societal harm [28]. Since organizations lack sufficient models to assess the direct and indirect damage from cyberattacks, analytical tools such as taxonomies are necessary: these contribute to the discourse on the subject. Analysis of the case studies also shows that organizations are unaware of the harm suffered by consumers or their employees. Therefore, without a holistic understanding of all potential harms, it is impossible for organizations to prioritize controls to mitigate those harms [28].

The German IT Grundschutz Methodology, which is based on Standard 200–2 of the Federal Office for Information Security (BSI) for the development of security concepts within an information security management system (ISMS) proposes the following six typical damage scenarios to clarify the concrete situation of institutions, be they authorities or companies ([29], pp. 79, 126): violation of laws, regulations, or contracts; impairment of the right to informational self-determination; impairment of the physical integrity of a person; impairment of the ability to perform tasks; negative internal or external effects; financial consequences. The damage that could occur if confidentiality, integrity, or availability is lost for a particular (business) process or for an IT system or an application including its data can usually be assigned to these typical damage scenarios [29]. Frequently, a single instance of loss or damage may involve several damage scenarios—thus, for example, failure of an application could

prevent essential work from being performed, resulting in direct financial loss and, at the same time, in a loss of reputation ([29], p. 79). However, additional scenarios could also be considered to capture the specific situation ([29]p. 80).

2.1 Topic “home office”

HO/WFH is the generic term for the concepts of telework, alternating telework, and mobile work. There are differences in Germany—e.g., with regard to labor and data protection. The sudden urgency of digitization has been made apparent by the pandemic, and the inhibition threshold in the use of digital tools has decreased among users [30]. In terms of the proportion of people working from home, Germany was below the EU average before the COVID-19 pandemic and well behind other countries such as France, the United Kingdom, and the Scandinavian countries [31]. Only 12 percent of all dependent employees in Germany worked mainly or occasionally from home, although this would theoretically be possible for 40 percent of jobs [31]. In most cases, the desire to work from home is thwarted by employers; according to Brenke, if they were to rethink their position, the proportion of teleworkers could rise to over 30 percent—the gap between employees’ desire for HO/WFH and the opportunities offered by employers was greatest in the financial sector and in public administration [31]. Because of the pandemic, statistics clearly show how HO/WFH has changed the CS landscape for businesses and created new risks [6]. A survey of 3000 remote office workers and IT professionals in the United States, United Kingdom, France, and Germany showed that 77 percent of remote workers use unmanaged, insecure bring your own devices (BYOD) to access corporate networks and data [6]. Additionally, 29 percent of employees surveyed said they allowed other members of their household to use their company computers for activities such as schoolwork, gaming, and shopping [6].

In addition, HO/WFH has become a very real experience for a large part of the population and also leads to concepts of entitlement. Practice shows, however, that the legal basis has not yet been properly prepared, even if the German Federal Ministry of Labor and Social Affairs (BMAS) is planning a legal right to HO/WFH [8]. The investigation by Barrein points out that a legal entitlement according to §8 TzBfG (law on part-time work and fixed-term employment contracts) proves to be only partially effective; instead, the legislature should promote regulations based on social partnership [8]. Antczak & Horzela point out that in Poland, too, the necessary legal and organizational solutions do not keep up with the speed and universality of the implementation of remote work and HO/WFH [32]. Irrespective of this legal problem and the various security problems, many authors assume that our way of working cannot be rolled back to the status quo before the pandemic. According to Borkovich & Skovira, the advantages of telework or HO/WFH include improved productivity and employee satisfaction, the reduction of unplanned absences, less time wasted, and a better work-life balance [33]. At the same time, employers can also benefit by, for example, saving on overhead costs, eliminating facilities and time zones, and reducing travel expenses [33]. However, the research of Borkovich & Skovira makes it clear that IT departments in general are overwhelmed by the task of controlling the ever-increasing email activities of employees. In addition, the corporate culture must be adapted because there is a general lack of open communication and transparent cooperation as well as constant feedback; they advocate six essential strategies to develop an inclusive HO/WFH corporate culture: control, collaboration, communication, cost, cloud, and culture [33].

According to Kellner et al., HO/WFH is rated more positively overall, with the advantages of flexibility of place and time, fewer interruptions, and increased concentration at work [30]. The merging of work and private life is mentioned as a disadvantage, as is a lack of contact, informal discussions, and spontaneity [30]. There is thus a growing need for a mixed form of office work and HO/WFH [30]. Using a survey module, Von Gaudecker et al. analyzed how working hours changed under the social distancing regulations enacted to combat the COVID-19 pandemic [34]. Examining the Netherlands as a prototypical Western European country, both in terms of its welfare system and its response to the pandemic, the authors show that the total number of hours is decreasing, especially among the self-employed and those with lower educational attainment [34]. An educational gap occurs because tertiary-educated workers work many more hours from home, the magnitude of this effect being tempered by the government's definition of some workers as essential to the functioning of the economy [34]. Cross-industry studies show that there are two clusters: one is office-like occupations with a high proportion of academics and HO/WFH hours; in the other, manual tasks and social interactions predominate, with low proportions of academics and HO/WFH hours [34]. Brenke confirms that—and this was the case even before the pandemic—well-qualified, full-time employees are particularly interested in HO/WFH [31]. The basic motive is apparently the desire for more autonomy in terms of time and not just the compatibility of work and family because singles want to work at home as often as single parents [31]. Teleworkers often have long working hours that are far above average and frequently do unpaid overtime—nevertheless, they are more satisfied with their work than other workers, especially those who would like to work from home but are not given the opportunity to do so [31]. Now that the pandemic has peaked, employees in the Netherlands expect these current patterns to continue [34]. They also expect a great deal from government support programs to help them keep their jobs—i.e., their expected response to unemployment is far lower than in the United States or United Kingdom [34]. This also makes the high demands on the welfare state clear, which is likely to be similar in Germany.

The results of [31, 34] are not surprising. Messenger & Gschwind remind us that as early as the 1970s and 1980s, Jack Nilles and Allan Toffler predicted that the work of the future would be moved to or near the homes of employees using technology dubbed “telecommuting” [35]. This “new ICT,” including smartphones and tablet computers, has changed work and life in the 21st century, which have been revolutionized by the detachment of work from classic office spaces, whereby technological progress has continuously promoted the development of telework in different phases [35]. According to Messenger & Gschwind, today's diverse, location-independent, technology-enabled new ways of working are all part of the same revolution in work-life interrelationships [35]. And the technological revolution is continuing. Owing to the ongoing pandemic and associated increase of HO/WFH in Germany, the use of (several) messengers (“multi-homing”) has increased in addition to telephone and e-mail ([36], p. 66). In 2021, 73 percent of users in Germany operated multi-homing, 83 percent used a messenger service at least weekly, and among the under-thirties, the figure was as high as 99 percent [36]. Apparently, messaging solutions are also enjoying increasing popularity in the federal administration environment and are used by many authorities [36]. However, when it comes to formal communication with companies, authorities, doctors, and other nonprivate addressees and organizations, many users stick to classic (mobile) telephony because of better accessibility ([37], p. 48).

Moreover, IoT comprises a wide range of different devices that receive and transmit data over a network without human intervention, thus connecting the digital world with our physical world [38]. In 2020, 11.7 billion connected IoT devices were actively used worldwide; by 2025, this number is expected to rise to over 30 billion, so that it is expected that there will be an average of four smart devices for every person [38]. The demand for IoT consumer (IoTC) products is growing and presents manufacturers, brand owners, and retailers with new challenges in the area of CS, because from smart televisions to cameras and scales to children's toys, every connected consumer product is a potential threat to data security and privacy, and manufacturers could be held accountable [38]. Back in December 2019, a hacker gained access to a surveillance camera and was able to molest an eight-year-old child [38]. The standard of the European Institute for Telecommunications Standards (ETSI) EN 303645 "Cyber Security for Consumer Internet of Things" has served security efforts since 2020; since 2018, the data protection provisions of the General Data Protection Regulation (GDPR) EU 2016/679 has come into effect; and the Radio Equipment Directive (RED) 2014/53/EU require IT security for all IoT devices from August 2024 on [38]. The challenge is to find the balance between usability, functionality, and security when developing new consumer devices—a well-known example from the past is the baby doll "Cayla," which was taken off the market by the German Federal Network Agency in 2017 [38].

According to Li et al., security education training and awareness (SETA) programs help organizations to mitigate security breaches caused by human error and to manage the security-related behavior of employees at work [9]. To do this, employees must be continuously made aware of IS and related policies and be able to apply them in their daily activities to prevent security incidents [9, 39]. Clear CS guidelines, effective training, and guidance from the organization result in a relatively high level of transparency regarding the responsibilities of employees [9]. Therefore, the cybersecurity behavior of citizens/employees is becoming a major concern in modern times, leading to an awareness of some unresearched challenges for individual CS behaviors [9]. The responsibility for protecting information and privacy security that individual users must bear is complicated [9]. This includes the perceived personal responsibility of users as well as the invisible responsibility of shared devices or networks in the home environment [9]. Thus, some users may be responsible for the CS of others at home and this may include children [9]. This feeds into the transparency of responsibility—i.e., the extent to which people understand the limits of their responsibility [9]. Responsibilities may lie on the software development side or with vendors, CS services, or users: the actors may believe that some CS operations were the responsibility of the other party, and no cybersecurity measures were taken, resulting in a vulnerable area in the home cybersecurity environment—accountability and accountability transparency have never been mentioned by individual users in previous studies, but they do impact CS behavior [9].

Furnell & Vasileiou also emphasize that CS is often seen as someone else's problem, with the result that the very parties who should be involved in it instead distance themselves from it. For example, end users often seem to assume that their employer, ISP, or some other party takes care of their security needs [40]. In reality, they themselves as individuals play an important role because no matter what steps are taken elsewhere, there will be some threats that reach them directly [40]. So, individuals will find that they need to make security-related decisions, and they clearly need some level of awareness and understanding to do so [40]. On the other hand, companies may unrealistically assume that their employees should already have

acquired general CS awareness elsewhere and feel that they do not have to take full responsibility [40]. One of the most important prerequisites is that the various stakeholders recognize and address their role [40]. In fact, a fundamental challenge is that we are not dealing with a situation that fits everyone—this has an impact on the target-group orientation of training and awareness-raising measures [40].

The cross-case analysis of Fallahdoust on HO/WFH offers three main results: (1) All cases show that almost no training material was produced due to the sudden shift to HO/WFH; (2) All cases indicated that they use streaming services on their work devices and felt the cyber risk to be low since they access their network through some form of authentication; (3) Lack of management involvement is highlighted as a major gap in fostering conversation and promoting safer CS behavior [14]. The following six-step method is proposed to design nudges [14]:

- Define an undesired cybersecurity behavior by identifying risky behavior.
- Identify and outline aspects of the choice environment—i.e., the context in which choices are made.
- Select aspect(s) of the choice environment to target.
- Propose an intervention to help channel undesired behavior into desired behavior.
- Implement the designed solution, or nudge, with a small control group at the organization, which is to measure its effectiveness—if successful, the solution is ready for mass implementation.
- Maintain monitoring and adjust the nudge as behavior changes.

2.2 Topic “awareness raising”

Proofpoint’s survey in 2022 asks, “Which of the following topics does your security awareness training program cover?” [19]. In the category “Recommended practices for working from home,” Germany scored just 25 percent, performing worst among the surveyed European countries France, Spain, and Great Britain and coming in significantly below the global average of 37 percent ([19], p. 48). This again confirms the statement that there was no training material produced in Germany owing to the sudden shift to HO/WFH. Brown sees the need for a move toward more widespread HO/WFH and increased acceptance of it but warns of the dangers to business processes, personal data, and critical infrastructures resulting from a lack of security of private networks and systems: “No one wants to be hacked. However, many people do not even know when they will be hacked or how to protect themselves” [41].

In 2017, almost half of European Internet users considered themselves well informed about cybercrime [42]. Further research by Vogels & Anderson has found that actual digital knowledge is limited in the general population, and levels of knowledge vary by educational level and age [43]. The representative survey of 967 respondents by De Kimpe et al. on perceived knowledge also revealed the following paradox: people who believe they are well informed enough about online risks see no need to take further measures against cybercrime, as they feel less vulnerable online,

while acknowledging the overall seriousness of cybercrime and empowered to take the right security measures [25]. Future cybercrime campaigns and awareness-raising interventions should, therefore, carefully adjust their communication and explicitly emphasize that any Internet user can become a victim of cybercrime [25]. It is recommended that future interventions include providing vivid, relatable, relevant messages as a form of indirect experience of cybercrime that could highlight the personal vulnerability of each Internet user (see also [44]). The emphasis on personal responsibility combined with the provision of vicarious experiences of online protection appear to have a positive impact on protection motivation if the message is tailored to the level of knowledge of the individual [25, 45].

The literature review by Aldawood & Skinner examined popular awareness-training solutions and techniques used by organizations to defend and mitigate CS social engineering threats. Recent training methods identified in this study include serious games, gamification, virtual labs, tournaments, simulations, and the use of other modern applications [46]. Up-to-date awareness programs that educate people about SE threats, including video streaming, compliance, topical training, awareness campaigns, and conferences, are used [46]. Training methods have changed over the years, with organizations using virtual and real scenarios and competitions to learn about social engineering threats and strategies to mitigate them [46]. The communication of real scenarios in working environments is becoming increasingly important; serious games and simulations are the most effective solutions against SE threats because in both cases real experiences with SE threat scenarios are used to raise awareness. Gamification, virtual labs, and tournaments also include similar physical and mental solutions [46]. However, it is currently unclear how gamification affects creativity vis-à-vis other forms of incentives [47]. For Aldawood & Skinner, the best solutions also include video tutorials on threats and mitigation methods, awareness conferences, training campaigns, and security reports—it seems to be a recipe for success [46].

When it comes to information security awareness training (ISAT), there is no doubt that merely imparting knowledge does not lead to the necessary awareness, appropriate risk assessment, or sustainable behavioral change in the area of IS and CS [48]. In addition, the key message that changing the behavior of employees cannot be achieved simply by imparting knowledge but must be accompanied by further measures has not yet got through to management, CISOs, and other C-level executives [48]. Moreover, the major problem with ISA is not a lack of security knowledge but the way that knowledge is applied in real-world situations [49]. According to Cialdini, those involved should be honestly informed about the damage caused by even a modicum of undesirable behavior [50].

Further research is needed to determine the extent to which emphasizing personal vulnerability would have a positive impact on user protection motivation and behavior [25]. Fear is not a good guide. Indeed, simply eliciting fear without incorporating actionable and effective recommendations stimulates fear control, leading to defense mechanisms to reduce fear rather than engaging in protective behaviors that would reduce threat [51]. A very interesting aspect, which is beyond the scope of this publication, is the extent to which the victim of a cybercrime act can themselves be held guilty. According to Machado & Gouveia, it is obvious that in most cases of cybercrime, the victim bears some complicity because individual careless behavior when using the Internet is a gift for cybercriminals [15]. For example, in Brazilian criminal law, the behavior of the victim is taken into account when determining the penalty handed down to the offender, and if the victim is solely at fault, no penalty

is imposed and the offender is released [15]. But such purely legal aspects go beyond this paper.

Borg & Unit stresses that the current formalization of (university) CS training risks actively preventing people from developing many of the skills and abilities that are most needed [52]. According to [52], too much focus is placed on the narrow technical part of the CS risk assessment, and both consequences and threats as well as economic viability, are ignored. It is necessary, instead, to do things that increase the costs for the attackers, and you also need people who can think things through over and over again and move between disciplines so casually that they hardly notice it [52]. Li et al. currently regard people's CS behavior as an important concern—another subject for future research [9]. Chaudhary et al. argue, that CSA is not only about knowledge but also about putting what you have learned into practice. It is an ongoing process that needs to be adjusted in subsequent iterations to improve its usability and sustainability [53]. This is only possible if a CSA program is reviewed and evaluated in a timely manner. Reviewing and evaluating an awareness program provides insight into the program's effectiveness on audiences and the organization, invaluable information for continuous improvement of the program; in addition, it provides the information that management and sponsors need to decide whether or not to invest in the program [53]. Despite these benefits, there is no common understanding of what factors to measure and how to measure them during the assessment process [53]. The authors adapted the European Literacy Policy Network's four indicators (impact, sustainability/long-term efficacy, accessibility, and monitoring) for awareness assessment to make them suitable for assessing a CSA program [53].

Through literature research, Chaudhary et al. summarize the following factors of a training program for evaluation: behavior, attitude, knowledge, interest (by audience/organizer/management), reachability (accessibility of awareness materials), touchability (self-motivated actions), value-added (nonfinancial/financial benefit), usability (relevant topics, delivery, practice, user confidence and satisfaction, usefulness of the awareness program) and the overall feedback [53]. Among all the factors measured, behavior, attitude, and knowledge are the most popular in literature; similarly, methods of measuring these factors can be broken down into survey, test, passive data, face-to-face interaction, and observation, with survey and passive data being the most popular [53]. Wang et al. are conducting a quantitative analysis of UK companies to examine the key elements contributing to SETA implementation [54]. Their results show that the awareness of the company management has the greatest influence on decision-making with regard to SETA implementation [54]. Moreover, most organizations generally lack awareness of CS protections for employees using externally hosted web services and products and services dependent on online services [54]. In addition, business leaders generally tend to minimize their budgets [54]. Ghafir et al. pointed out that the lack of corporate training budgets negatively influences employee awareness training [55].

3. The project's goal and serious games

The information and experience compiled in our current complex project with pilot companies should enable the management, acting together with CISOs, to initiate training and further educational measures tailored to the needs of the specific working groups. In study 1, interviews were carried out to ascertain the main IS/CS issues of interest to the companies [56, 57]. An online survey was also conducted and evaluated

as report 1, allowing security profiles to be developed [58]. The results provided the basis on which to build an innovative overall scenario for IS/CS in SMEs and develop seven analog and seven digital serious games as well as seven on-site learning attacks geared to the main topics in order to raise awareness. ISA/CSA in the organizational context can be defined as the extent to which staff understand the importance of IS/CS, the level of security required by the organization, and their individual security responsibilities [59]. It is important to arouse positive emotions in employees when raising their ISA—this can be done by integrating emotional design into awareness-raising measures [60]. Our project is named “Awareness Lab SME (ALARM) Information Security” and funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK). It runs from October 1, 2020, to September 30, 2023. The BMWK only allows learning scenarios for German SMEs to be developed in German: the final versions can be used free of charge by all organizations for internal, noncommercial purposes and will be available from the project website in September 2023 [61]. The overall approach of the project is summarized in [62].

The IS topics relevant to SMEs emerged from the first study of our project for the analysis of the current situation, which is based on in-depth psychological interviews with four pilot SMEs. The topics formed the basis of the development of both the analog and digital game-based learning scenarios and the on-site attacks. Their working titles were [56, 57]:

1. Password security.
2. Phishing, CEO fraud & co.
3. Social Engineering, manipulation & co.
4. Apps, software & co.
5. Safe & secure in the home office.
6. Data protection in the cloud and data protection in the context of customers and suppliers.
7. Messenger, secure transmission, storage, encryption & co.
8. Information classification.

3.1 Analog games

The project’s subcontractor, “known_sense” has been committed to lively communication on the subject of security and effective awareness raising since 2002 and has extensive experience in the conception and development of analog serious security games. The firm known_sense began collecting ideas at the end of 2020, aware of the risks that were being amplified by the pandemic, especially in the home office. However, as the first project task, in-depth psychological interviews on the current situation of German medium-sized companies had to be carried out in order to obtain a solid impact study of the initial situation [56, 57].

Based on these findings on relevant IS topics, the subcontractor, together with the project team from known_sense, defined seven game-based, analog learning scenarios

that are to be designed, developed, visualized, and produced during the project period until September 2023. Based on our shared experiences from past projects, we have planned three iterations for each analog learning scenario:

- First, the subcontractor proposes a learning scenario on the defined topic, which is optimized together with the university's project team.
- The learning scenario is then tested by the project's pilot companies and further improved based on their feedback.
- As the third iteration, the improved learning scenario is tested with external SMEs from the customer environment and at public events. Based on these experiences, the final version of the learning scenario is developed and produced.

The tests to be carried out in three iterations per analog game with participants present make it clear whether the complexity of the topic should be reduced, the attractiveness of the game can be improved, and the design needs to be optimized for an emotional game design. The prefinal titles of the seven analog learning scenarios (LS) are [63]:

LS 1: Living safely and working securely from home (home office).

LS 2: Password protection and multi-factor authentication.

LS 3: The five phases of CEO fraud.

LS 4: Mobile communication, apps & co.

LS 5: Cyber Pairs (social engineering methods).

LS 6: Data and information protection.

LS 7: Information classes roulette.

Two of the seven analog learning scenarios are presented in this publication: namely, “Living safely and working securely from home” (LS 1) and “Mobile communication, apps & co.” (LS 4). The analog serious games are designed as assignment games for the topics defined by the pilot SMEs in study 1 [56, 57], so that a moderator can easily get into conversation with the participants and the participants with each other, giving them a chance to contribute their experience. Characteristics of each of our analog learning scenarios are:

- Tests in three iterations per game within the project
- Play time reducible to 15 min.: approx. 3–5 min. Start (“pick up”), approx. 8–5 min. Play (“active doing”), approx. 4–5 min. End (“mnemonics/golden rules”)
- Various tests in practice with different target groups outside of the project's participants
- Users' feedback used for continuous improvement

Figure 1 shows some pictures of the use of such games with interesting comments from analog awareness training. Such tests, to be carried out with attending participants in three iterations per game, are used both to simplify the complexity of the topics while maintaining the attractiveness of the game and to optimize the emotional game design. The response has been very positive so far, not only from tests with the

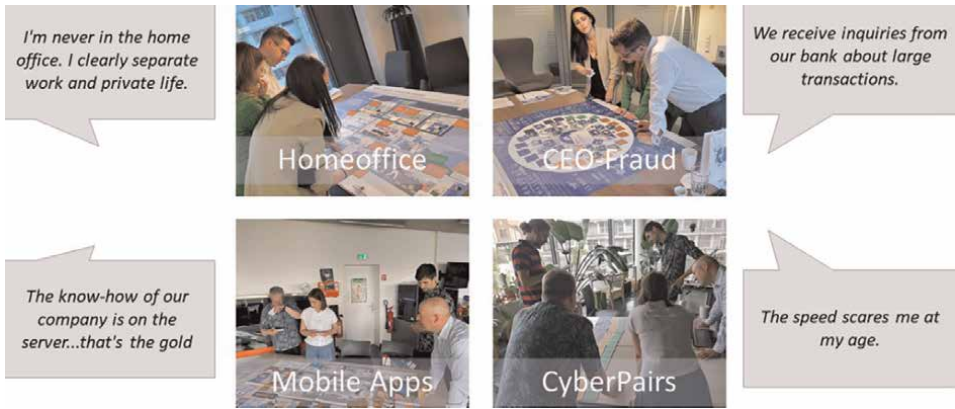


Figure 1. Some comments in training with four analog serious games to raise awareness of information security for the topics home office, CEO fraud, mobile communication, and cyber pairs.

pilot companies but also at public events. Improving the detailed preparation of the feedback is an ongoing process in the project.

3.1.1 The analog game “living safely and working securely from home”

This game on the subject of HO/WFH consists of a plastic board, foil, or plot with an original size of 168 cm × 118 cm, showing a large family house set up as a learning scenario (see **Figure 2**). The board should be laid out on a correspondingly large table. This playing area is also available as a poster on a pinboard. A moderator briefly introduces themselves and the topic of this learning station. They ask the participants about their experiences, problems, and solutions in the home office or with smart IoT applications and let the participants briefly talk about these issues. The moderator then briefly explains the course of the game. This introductory phase should last a maximum of 5 minutes.

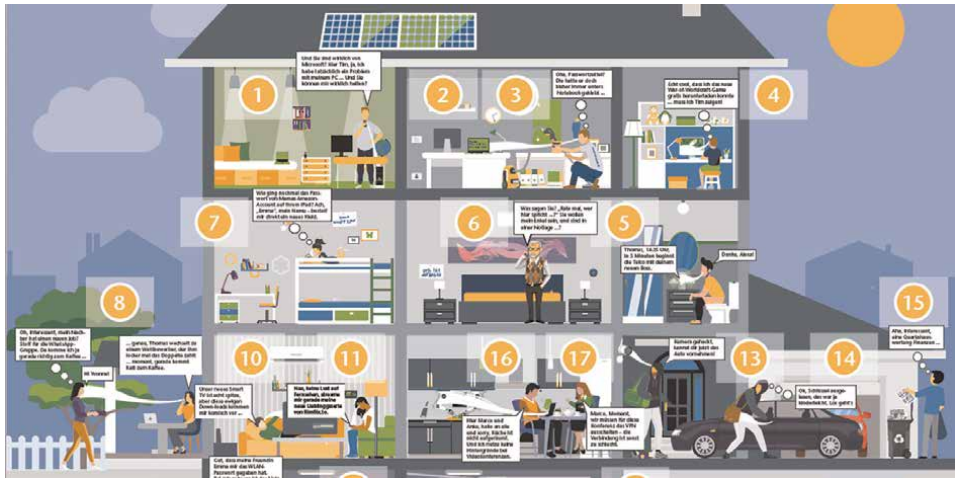


Figure 2. Large board as lively picture (hidden-object puzzle) and playing area for the analog serious game “living safely and working securely from home,” prefinal version 2022.

A total of 17 aspects, numbered from 1 to 17 on the board, need to be dealt with by the players in the prefinal version of the game. There are orange risk cards in DIN B7 size on which the various security risks that can be encountered in the home environment are described in two to three sentences. In the first phase of the game, these risk cards are distributed to the participants by the moderator; they read out the risks, and together, they try to find the situation on the board and place the card accordingly. In the second phase of the game, green defense cards are distributed, which represent protective measures and, thus, solutions for the risks shown on the risk cards. The green defense cards are also to be placed on the board. The moderator can use a stopwatch. Both phases of the game should only last 2.5 to 3 minutes. For larger groups of participants, it can be useful to have participants act together as pairs.

The final phase is followed by a debriefing of 4 to 5 minutes in which incorrect assignments or unresolved questions are clarified. If the learning scenario is used in a competition with several teams of participants, the moderator awards points to each team for the correct allocation of the cards and takes all the cards off the board before the next team arrives. Briefings (instructions, solution sheets, and golden rules) are available for the moderator. We recommend having teams of up to 12 people, so—in a circle training with four different analog learning scenarios—48 people would tackle four topics in 1 hour.

An example of an orange-colored “risk card” (prefinal version) is shown in **Table 1**. In the first phase of the serious game, this card should be matched to the correct number (#16) on the board shown in **Figure 2**. This provides insights into the private sphere of employees. Unless work and home are separated, my private life is exposed to all the participants in a video conference; at larger conferences, it is also easy to lose track of who is attending and what will happen to the information about me and my private life. The prefinal version of the learning scenario recommends as a security measure (green card, not shown) that the backgrounds for video conferences be adjusted and that very private things be placed out of the webcam’s field of view, especially if the participants are unknown. A test run with the camera should also be carried out (privately) before such a conference.

The green protection card Q, shown in **Table 2**, should be assigned to the situation with the number 17 on the board (see **Figure 2**). It recommends only exchanging sensitive information via a virtual private network (VPN) to be provided by the employer. In order to guarantee the necessary transmission speed, the video function should be switched off if necessary. It is also noted on the protection card that the expertise of the company’s IT administrator should be included to help secure conferencing platforms and establish stable connections. The risk card laid out beforehand makes it clear that if processing, conversations, or video conferences in which sensitive data is exchanged take place without a VPN (because of the supposedly slower transmission speed), attackers can eavesdrop and read the data.

Tiefe Einblicke in die Privatsphäre Ohne Trennung von Arbeit und Wohnen können bei Videokonferenzen alle Einblicke ins Privatleben erhalten. Bei größeren Konferenzen verliert man leicht den Überblick, wer teilnimmt und welchen Weg Informationen über mich einschlagen.	In-depth insights into privacy: Unless work and home are separated, your private sphere can be seen by everyone in a video conference. At larger conferences, it's easy to lose track of who's attending and where information about me is going.
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Table 1.
*Example of an orange-colored risk card to be matched to the correct number on the board in **Figure 2** as the first phase in playing the learning scenario as serious game (German left, English translation right).*

<p>Q</p> <p>Austausch sensibler Informationen nur über VPN vornehmen. Um die notwendige Übertragungsgeschwindigkeit zu garantieren, ggf. Videoübertragung ausschalten. Expertise des IT-Admins hinsichtlich sicherer Konferenzplattformen und Herstellung stabiler Verbindungen einbeziehen.</p>	<p>Only exchange sensitive information via a VPN. In order to guarantee the necessary transmission speed, switch off the video function if necessary. Include the IT admin's expertise on secure conferencing platforms and establishing stable connections.</p>
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Table 2.
*Example of a green-colored “protection card” (prefinal version) to be matched to the correct number (#17) on the board shown in **Figure 2** as the second phase in playing the serious game (German left, English translation right).*



Figure 3.
*Game situation with the assignment of cards to the scenarios presented on the analog board shown in **Figure 2**.*

Figure 3 clarifies the specific game situation with the assignment of the cards by the participating players. The moderator is given a summary showing the correct assignment of the orange and green cards, so that they can quickly correct the participants' solutions as part of the game or in a follow-up session (not shown). During the debriefing, which is the third phase of the serious game, the participants should be given so-called “golden rules” orally or by printout. These rules underline that the separation of private life and working life makes both areas safer and more secure. Specifically, the following advice can be given:

- The same security requirements apply in the home office as in the workplace.
- Working from home should only be done with the tools provided or approved by the company.
- No processing of company-internal or (strictly) confidential information takes place in the private IT environment (personal PC, hard drive, etc.).
- Only the information and documents that are really needed and are explicitly allowed should be taken home.

- It is best to lock documents away because the same applies in the private sphere: all sensitive data must be kept safe not only from children but also from visitors and, if applicable, domestic staff.
- Protect computers from outside eyes and always lock them when leaving the workplace.
- Always think of potential viewers and listeners: it is sometimes pleasant to work on your own terrace or at the open window, but this is usually not very discreet.
- In the event of a security incident, company-defined reporting methods must be used.
- In addition, the private infrastructure must always be kept up-to-date—routers, virus protection, firewalls, and all smart devices must be provided with their own passwords and updates.

3.1.2 The analog game “mobile communication, apps & co.”

Mobile communication using apps is also closely linked to HO/WFH. Since work today is often hybrid, mobile communication, apps, and software are still an important topics in SMEs (see study 1 [56, 57]). The corresponding analog learning scenario is actually very similar to the home office scenario explained above (see **Figures 2** and **4**): it also makes use of a large board as a kind of “hidden-object puzzle” with orange risk cards and green protection cards. This type of puzzle—i.e., a picture showing a busy scene—is always useful when the IS topic under consideration applies to different contexts. The participants can very quickly immerse themselves in the scenes shown as a picture story. Here, in the analog game “Mobile communication, apps & co.,” there are 12 scenes (numbered #1 to #12) with smartphone or app usage



Figure 4. Structure of the analog learning scenario “Mobile communication, apps & co.” as a picture showing busy scenes with short story descriptions and visualizations centered on the use of smartphones and apps (prefinal version 2022).

taking place on three levels in a subway station and a house in the background. The scenes show different people using different smartphone apps. Here, too, the participants should find, discuss, and understand the IS/DP risks and assign appropriate security measures. In terms of the process, a procedure analog to the learning scenario described in 3.1.1 is recommended. However, the other five analog learning scenarios developed in our project are structured completely differently—only these two have the same didactic character.

In the initial phase, the moderator may ask the following question: What are the risks and other disadvantages of using apps that are popular as Internet services? Social media/networks, music, and video streaming sites, appointment planners, online games, web conferencing platforms, translation, presentation, cloud services, and e-mail services can be mentioned here. The moderator can also have the participant team estimate what percentage of apps steal data. A test procedure developed by the German TÜV [38] showed that of the 500 apps tested, around 40 percent of the programs read data without this being necessary for their function. When assigning the risks and the measures to address them, additional disruption cards that do not match the situations presented can be mixed in, in order to increase the participants' attention. In the final phase of the serious game, the question of where to find the security settings on your own smartphone can be addressed. If more time than 15 minutes is available, the moderator should go through the security settings of individual apps and discuss the pros and cons of each configuration. There are also extensive instructions given for the moderator in this learning scenario.

Mnemonics, like “golden rules,” should also lead to discussion and an exchange of experiences between the participants. The guide also provides the moderator with sample questions to stimulate discussion. The moderator should be well-prepared for the game. The golden rules of this serious game relate to the following aspects:

- Only install apps from trusted sources; apps can be gateways for malware and cybercriminals, promoting identity theft and manipulation.
- As a rule, you install apps on all your mobile devices at your own risk—you should inform yourself about possible risks.
- Remove apps you no longer use because each additional app is a security hole. Ideally, turn off services that are not needed.
- With each installation, pay attention to the rights that each app demands. If you allow access to the microphone or camera, there is a risk that your device will be used as a mobile bug.
- Do not tamper with your device by jailbreaking (iPhone) or rooting (Android), as this will compromise your security settings and device warranty.
- When using apps or Internet services, you always transfer data that may be stored, processed, and possibly published or otherwise used in third countries outside the EU. As there is often a lack of transparency about the data protection guidelines of numerous providers, you should expect individual items of data to be systematically analyzed and used in attacks on organizations (e.g., for espionage purposes).

3.1.3 Implications for the other five analog serious games

For the five further analog learning scenarios that have been developed, it is easy to extrapolate their importance for HO/WFH. Depending on actual company practice, circuit training can be set up in combination with the other learning scenarios as learning stations. If, for example, the manipulation of people—i.e., social engineering—is an important aspect, then it may be useful to train the definition of terms (LS 5: “Cyber Pairs”) and CEO fraud (LS 3: “The five phases of CEO fraud”). If, on the other hand, the classification of data and data protection are of central importance in the operational processes, the sixth (LS 6: “Data and information protection”) and seventh learning scenarios (LS 7: “Information classes roulette”) can be used in a targeted manner.

It is very likely that the second learning scenario (LS 2: “Password protection and multi-factor authentication”) will always be important in relation to HO/WFH. Password security is only as good as the people who use it, who often lack the motivation to apply optimal password security [64]. In 2022, every fifth adult in Germany will have been a victim of an attempted smartphone scam—two million people, in other words; among those under 30, the figure is as high as 30 percent, but the number of unreported cases is likely to be even higher [64]. Here, both IS and DP try to increase security through two-factor authentication (2FA) so that no unauthorized third parties gain access to the accounts. 2FA ensures that nobody can access the account without the express consent or at least the knowledge of the account holder—even if the access data becomes known by accident or was captured by a hacker attack [64]. In companies, the implementation of 2FA is therefore an important step in increasing data security for employees and guaranteeing the protection of their customers’ personal data. However, this requires additional effort for employees or users in general: instead of simply entering a password, a code must be generated, or a device must be kept ready [64], which is why users must be made aware of this.

A good first step is to raise awareness of password security and make clear to users the possible consequences of their carelessness [64]—this is shown separately in the analog scenario LS 2. It is one way to educate employees about the importance of IS/DP through the use of narrative games in an analog discursive setting specifically designed to raise awareness, providing a fun and interactive way of protecting their own and customer data. With increasing digitization, IS/DP are critical concerns for organizations of all sizes. With an increasing number of employees shifting to HO/WFH, companies are facing new challenges when it comes to protecting their sensitive data and IT systems. Remote workers may not have the same security awareness and training as those working in a traditional office environment, making it important for organizations to find effective ways to train their remote workforce.

3.2 The digital serious games

3.2.1 Overview of the digital learning scenarios

The subcontractor, Gamebook Studio, provides the easy-to-use and comprehensive toolset Gamebook Technology for the development of digital serious games based on storytelling. It includes the use of the Visual Novel format to integrate a player as an active participant in their own story in a simple manner. The project’s seven digital learning scenarios (**Figure 5**) are being developed by this subcontractor in consultation with the research team of the university. The digital games are not a simple



Figure 5.

In our project, seven digital learning scenarios are developed to increase the ISA of employees in German SMEs. Of these, the home office (red border) is presented in more detail in this paper. These game developments are only funded in German. In addition, an eighth digital LS is developed by the research group. They can all be played in German directly from the project website [61].

reflection of the analog variants because they are intended to generate independent motivation for addressing the issues, with employees targeted as different types of learners. The variety of different perspectives also has two positive effects: on the one hand, it ensures that playing does not become boring and that the motivation to learn is sustained; on the other, it conveys the relevance of the various actors and their methods within IS/CS.

All the decisions that the player has to make influence the course of the game. Every game decision not only affects their personalized story but also differentiates the topic in more depth and thus offers different learning paths and levels of difficulty—depending on your previous knowledge, personal strengths and weaknesses, and learning preferences. This means that every type of learner and every level of knowledge is addressed with decisions, and the format is therefore suitable for use in a particularly broad target group.

In contrast to the analog version, the digital scenario is played by the employee working alone at a time and location of their choice. Therefore, the discursive environment within the digital game must be determined by the player's decisions—the game designer has an important task here to develop the story and the learning paths in an appropriate and appealing way. The more successful the designer is in this, the more the story will stick in the learner's memory. In addition, a discussion of the digital learning scenarios should take place within the company afterward—with an active, in-depth focus on IS/DP to anchor what has been learned over the long term. The debriefings of serious games are very important for the learners. The final titles of the seven digital learning scenarios are as follows (see [61], in German):

- LS1: The first day (social engineering & password protection).
- LS2: The hacker attack (social engineering; methods & tools).
- LS3: The search for clues (CEO fraud: methods and protective measures).
- LS4: AI in the home office (protective measures home office & smartphone).
- LS5: Everything just stolen (password hacking methods & password protection).
- LS6: A classification in itself (information classification & purpose).
- LS7: The ransomware attack (encryption & messenger services).

In addition, an eighth digital LS was developed by the research group:
LS 8: Password hacking (crack a social media profile).

3.2.2 The digital serious game “AI in the home office (protective measures home office & smartphone)”

The next figure shows the decision tree (Figure 6, left column) of the digital game “Artificial Intelligence (AI) in the home office”—represented here in a very rough

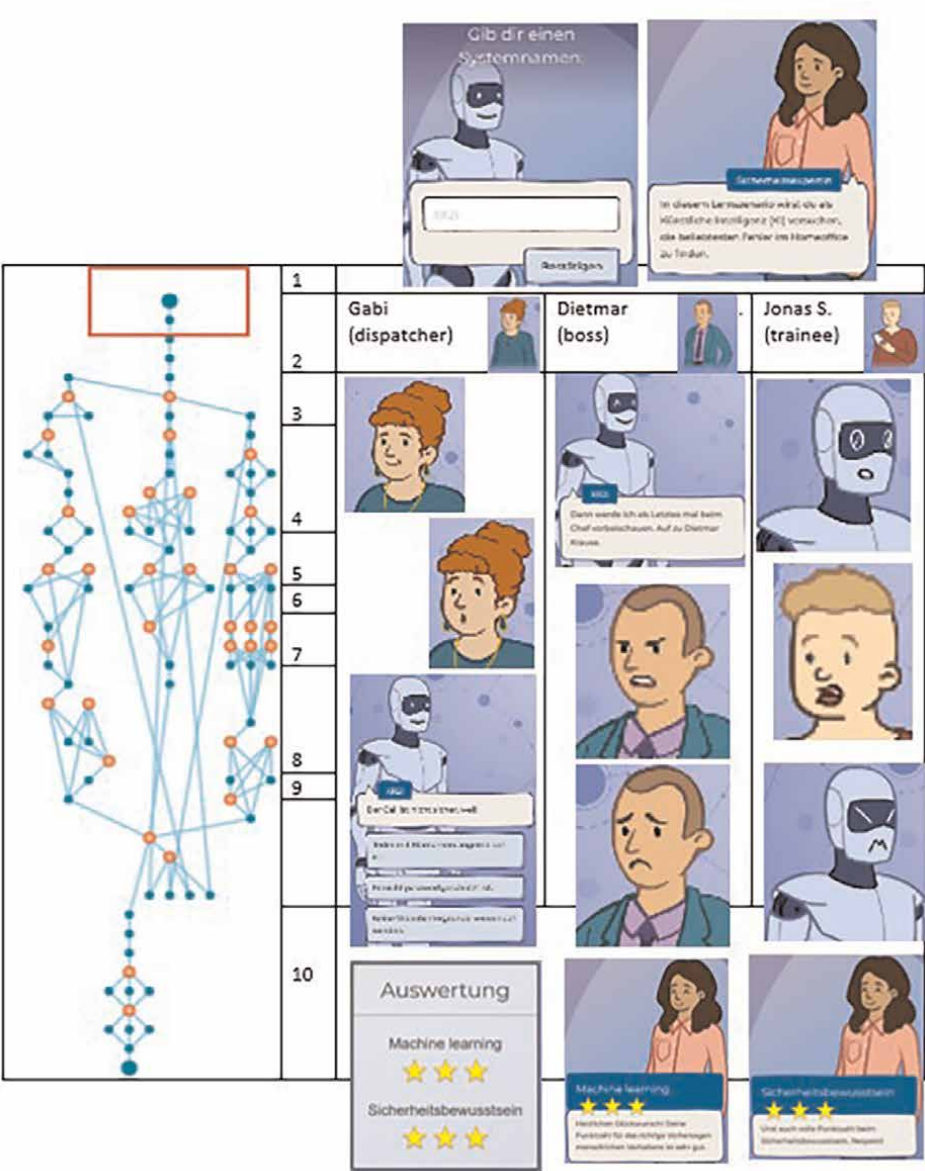


Figure 6.
Digital learning scenario under development (prefinal version). The rough decision tree of the story “AI in the home office” (left) and sample scenes for the three paths (right) with ten positions—See text for explanation.

form—which the player goes through in the role of an AI. At the very beginning of the game (number 1 in **Figure 6**), the player is given general information. Green nodes in the decision tree are “story modules,” providing the player with information presented as text, instructions, feedback, or even music. **Figure 6** (right) shows representative images of the information security officer (ISO), who gives the player initial information about their task, and the AI avatar, whose name should be given by the player. The ISO also explains that whatever decisions the player makes will affect how the game progresses. The decisions to be made should therefore be well considered by the player, since the goal is to pick up on the AI’s recommendations for a secure but livable way of working from home. The ISO also explains that the player’s points will be counted, and both his efficiency and social skills will be analyzed. In this case, efficiency means whether and how quickly the player catches on to what the AI recommends. At the end (number 10 in **Figure 6**), feedback is given on how much learning content the player has discovered along the way and their score in the form of stars. A maximum of three stars can be obtained for learning and for the security awareness they have demonstrated. At the very end of the learning scenario, reference is made to the other six digital learning scenarios.

The actual story starts at the next green node, identified by the number 2 in **Figure 6**—the decision as to which home office should be examined first by the AI: the images corresponding to the possible choices can be seen on the right. The three paths correspond to the home office of the dispatcher, Gabi Burgmeister (second column in **Figure 6**), the boss, Dietmar Krause (third column), and the trainee, Jonas Schmidt (fourth column). The numbers 3 to 9 in the particular path that has been selected refer to the decision as to which questions the AI should ask the people working in the home office. To the right of this are sample images of the scenes for the particular path. It is also evident that the avatars are able to show emotions. In the digital game, sounds and music can be heard to accompany the situation, but the avatars do not speak. The decision options are presented to the player in the form of text, so that the player has time to think about the question. The development of the storyline (first column in **Figure 6**) shows how important the designer’s empathy with the topic and the target group is in building the story.

As an example, for the entire learning scenario, the following information is given for numbers 1 to 10 and the player is asked to make decisions.

- Number 1 (**Figure 6**):
 - The security expert welcomes the player and informs them about the content of the learning scenario as follows: “In this learning scenario, you will try, as an artificial intelligence (AI), to find the most common mistakes in the home office. I pay attention to security awareness and whether you can correctly predict human behavior (machine learning). During the evaluation at the end, I will give you more detailed feedback on this.”
 - The player is asked to enter a system name as an AI. It is then made clear to them that in the company under consideration, most of the employees are currently working from home. In order to ensure more security, there, the branch manager Dietmar Krause decided to start a test run with AI software. After a successful attempt in the branch, it should now check the home offices of the individual employees. However, the AI is still in the testing phase.

- The player also experiences the AI's thoughts as follows: “Oh, these humans! Now it is all down to this cluster of organic cells whether I can show what you need for real security in the home office. Because if this little experiment goes well, I will be featured at the Security Software Convention and hopefully get to market then. Unless that faulty biomass throws a spanner in the works! Then it goes back into the development process and I get reprogrammed. But I know how to prevent that ...”
- The player then learns about their specific task as an AI. They have the opportunity to go to the home office of three different employees and look for weak points there. As an AI, the player may also be able to prevent errors by correctly predicting human behavior.
- Number 2 (**Figure 6**):
 - The player as AI is asked whose home office they would like to check. There are three people to choose from: the dispatcher, Gabi Burgmeister; the branch manager, Dietmar Krause; and the trainee, Jonas Schmidt.
- Numbers 3–8 (**Figure 6**) for HO/WFH of Gabi Burgmeister:
 - The player learns from Gabi Burgmeister that she lives alone with a dog named Wauzi. They learn the name of the Wireless Local Area Network (WLAN) and the registered laptop and an Android tablet. The AI introduces itself to Gabi, who, after a brief shock, remembers that the branch manager had mentioned something like that. The AI explains its mission to check the home office for security vulnerabilities and begins to scan Gabi's network environment.
 - For example, the player is asked what vulnerabilities they are likely to find and should decide between the following:
 - “The router probably still has its default password.”
 - “The microphone is probably always on.”
 - “The WiFi signal at work is probably weak.”
 - The router is the right choice here and the AI recommends that Gabi change the password of her router and her network as a matter of urgency. Gabi asks, “But why? The password is super long. So, it has to be secure, does not it?” The AI explains that lists of standard passwords are circulating and that hackers can gain access to the home network in no time at all.
- Numbers 3–8 (**Figure 6**) for HO/WFH of Dietmar Krause:
 - The AI reports to the boss, Dietmar Krause, via his smart speaker. The player learns that Dietmar Krause lives with his wife and two children in a terraced house that has been set up as a smart home. All residents share computers and other end devices.

- With the information that the workforce of the Grüsselig company is in the home office three out of five working days, the player must decide whether all employees of the company should:
 - “have company computers made available”;
 - “be paid a bonus because the company saves electricity”; or
 - “be provided with guidelines on ‘Security in the home office.’”
- The AI explains that clear guidelines and protocols are the be-all and end-all of a functioning security architecture and can be implemented without great technical effort.
- As the story progresses, the AI takes control of all the devices in Dietmar Krause’s smart home in order to optimize it. The player has to specify his first course of action:
 - “Establish physical protection against eavesdropping.”
 - “Maximize Internet security.”
 - “Update all devices.”
- The AI informs the player that regular updates are important to close security gaps and keep the smart home up-to-date. The player must then specify their further course of action.
- If the player selects “Maximize Internet security,” the AI disconnects all Internet connections in the home that are not immediately identified as work-related. The result is that the son can no longer play a console and complains, whereupon Dietmar Krause makes it clear that this is going too far and that all residents are allowed to use the Internet.
- The establishment of physical protection against eavesdropping means that all doors in the house are locked. However, Mr. Krause’s wife does not want to be locked up. She wants to talk on her cell phone on the balcony, while the AI sees this as a security risk, since someone could overhear what she is saying.
- After this situation has also been resolved, contrary to the AI’s advice, the AI realizes that all smart home devices still have their default passwords and third-rate criminals could hijack the devices and cause a situation like the one just shown. The AI suggests introducing a uniform level of security for the workforce and keeping the device software up-to-date. From a cost-benefit point of view, the player needs, among other things, to establish a VPN system for all employees.

- Numbers 3–8 (**Figure 6**) for HO/WFH of Jonas Schmidt:
 - The trainee, Jonas Schmidt, is the youngest employee in the company and has not agreed to the home office security measure by the AI. Nevertheless, the player as an AI must decide whether he first
 - “checked the router”; or
 - “looked through the webcam.”
 - The webcam reveals a Scarface movie poster, the book The Bitcoin Bible, and a few protein products. Jonas apparently lives in a shared apartment with at least three people. Eight devices (computers, mobile phones, tablets) are logged into the network. No major security measures can be seen, and the WLAN name is “Alice im WunderLAN.” The player should decide the probability of whether more than 10 people know the password for the network. The AI also draws attention to dubious websites and malware threats.
 - The AI wants to send Jonas a message on his phone, and the player decides which of the messages to take. The AI explains to Jonas that it determined his password from information that it collected with the help of his webcam. The player must now decide what the password for the account “JoSchmi02” is:
 - “Snailsweet2”
 - “KryptoMontana1312”
 - “JohnnyJungle@420”
 - In the conversation between Jonas and the AI, the player must also choose one piece of advice for Jonas:
 - “Cover the webcam when it’s not in use.”
 - “Delete your browsing history regularly.”
 - “Have no hints of passwords in your webcam image.”
 - Finally, the AI suggests creating an extra access for guests in the home network of the shared apartment.

At number 9 in **Figure 6**, the three stories, which can be played in any order, are merged. The feedback for the played digital game at the end (number 10 in **Figure 6**) is divided into two sections. Under “Machine learning” the correct prediction of human behavior is assessed, and under “Security awareness” the answers are evaluated. A maximum of three stars is possible in both categories.

4. Discussion

The term “serious game” is established nowadays, but there is no unique definition of the concept because it refers to a wide range of applications: they are used for

training, advertising, simulation, or education and are designed to run on different systems [65]. According to the technical report by Susi et al., serious games focus on learning with practical simulations for problem solving, with a number of positive effects when it comes to informing, learning, developing skills, social interaction, and psychological aspects [65]. However, there seems to be no conclusive evidence to support the much-vaunted usefulness of serious games, so research should focus on explaining why and under what conditions these games are compelling and effective [65]. Laamarti et al. give special attention to the design of digital serious games and their development, and the game developer must strike a balance between the fun factor and the game's main purpose [66]. In recent years, serious games have emerged as a new educational approach in IS that creates a fun, enjoyable environment in which users can experience attacks and practice appropriate behavior to protect information assets; ISA often only involves the transfer of knowledge—e.g., via a web-based training or a lecture [67].

According to Hart et al. there is a lack of pedagogically motivated methods and tools to support the design of serious games and to ensure that they achieve the learning goals [68]. Brown & Vaughan argue, “The ability to play is critical not only to being happy but also to sustaining social relationships and being a creative, innovative person” ([69], p. 6). In our opinion, based on our diverse experience with serious games in the field of IS/DP, emotional design should be integrated into the learning materials through the use of games and game elements [60, 70]. Meaningful narratives support immersion in serious games, which is crucial for learning success [71]. Green argues that stories support teaching as they:

- are more suited to raising interest in a topic compared to, for example, PowerPoint slides conveying information and hard facts;
- give the learning material a context so that the individual learning elements are easier to recall—for example, by creating vivid images; and
- help motivate learners to engage with abstract, possibly challenging learning content, inasmuch as they provide a nonthreatening way into a topic [72].

According to Landrum et al., stories also make the learning content personally relevant and thereby support the learning process [73]. Because of these benefits, research documents the effectiveness of storytelling for teaching and learning. The main benefit of storytelling is that its narrative structure and the emotional involvement of learners promote retention of the learning content [73]. Thus, good narratives of serious games invite the player to participate in the story and decide on the development of the story, thus encouraging the intrinsic motivation to learn. It is recommended that the narratives stimulate the imagination and include characters with whom learners can empathize [73].

Our analog and digital learning scenarios (serious games) for raising ISA/CSA—as described in Section 3—are being developed and improved with target groups in three stages of iteration. They use emotional designs with storytelling and interactions in discursive settings. To help raise awareness in IS/DP, the complexity of the topics needs to be reduced. Moreover, each game should be shortened, with a maximum time limit of 15 minutes, so that it can be played by employees in a break or together with other games in an effective circuit training. On the other hand, if more time is available, each topic can be presented and discussed in depth; above all, the

experiences of the participants should be included again and again, so that a more in-depth training of 1 hour can result. Both our analog and digital learning scenarios can therefore be used flexibly: they can deal with the topic in a reduced or extended way.

The prefinal analog learning scenarios were also evaluated by external SMEs [63]. The “safe living and secure working from home” learning scenario showed the fewest obstacles for learners in the tests and evaluations. In general, our experience with such pictures of busy scenes like this, in which “risk cards” and “protection cards” are matched, is that they all work equally well. The principle of the game does not have to be explained at length by the moderator but is adopted automatically by the participants after a few seconds. The learners understand the game and their task immediately. With risk scenarios that are mostly familiar, this learning scenario is an ideal “soft start” to a learning course including the other six games on the subject of IS/CS. Some spontaneous responses from participants are given as examples [63]:

- “It fosters a sense of achievement. You do not feel totally helpless.”
- “It’s just like in real life—video conferencing with the boss while the children are yelling or crying close by.”
- “Actually, this is all clear, and yet it’s something that happens to you.”

The participants usually seem grateful to be able to review their own experience of working from home, which became much more prevalent as a result of the pandemic, in relation to IS/CS and DP. Both business and private issues are addressed together. Many employees often discuss examples from their own environment, and younger people, in particular, cite things that happened to their own parents or grandparents [63]. The advantages and disadvantages of working from home and in the office are compared, and people’s motivation and fears are discussed. Laughter is triggered by the idea of the number “Alexa in the toilet” (#xx), and the game is completed quickly despite a lively discussion [63]. In all cases, the correct assignment of the 34 cards to the 17 scenarios is relatively quick—the 5 minutes of playing time are usually sufficient without the moderator having to motivate participants to go faster. In rare individual cases when the visualization of a station number cannot be understood immediately, talking with the other participants or the moderator helps bring clarity. During the debriefing, the importance of the topic is emphasized, and the implementation is praised. The game of this LS is rated, relatively speaking, as “easily solvable” and “extremely practical” [63]. From the point of view of the evaluation [63], there was no need for any changes to the final version of the game.

The in-depth discussion in the context of IS enables participants to understand the meaning and purpose of the digital tools, informed by an increasingly critical attitude toward their own working conditions. At the same time, it is often clear that employees in SMEs are relatively unconcerned about facing personal consequences if they make a mistake [56, 57, 63]; this also reveals deficits in the operational safety culture. All in all, with the help of analog games, the employees seem to be able to develop an awareness that seems interesting to them and takes on a life of its own, encouraging them to delve further into the topic. This is brought out by the abundance of lively, in-depth questions from the participants. Moreover, gamification can have a positive impact on creativity [47]. The consistently high interest of our participants was also reflected in inquiries about content that may not be covered by the learning scenarios. This was coupled with a significant stretching of the tight time

limit of 15 minutes set aside for the task. However, all our analog learning scenarios are flexible and can be extended in terms of content.

In the learning scenario related to living and working safely from home, the authors of study 2 recommend addressing the typical home office risks mixed in with risks deriving from IoT or Smart Home, since IoT devices all rely on the same network, which is used when working in the home office. This means that the use of smart devices entails additional risks for projects that are brought home from work, unsupervised by the employer, for further elaboration on the network, possibly involving private hardware. Discussions of this kind help participants learn to pay more attention to IS in their own company and to recognize the connection (the same network) between business and private use [63]. By their very nature, the analog games for IS include the necessary interaction and discussion as part of the visualized story/narrative. This helps participants internalize and remember the content. Our own experience of using these games consistently shows that the debriefing, however brief, is very important.

Our experience creating three agile iterations for the digital learning scenarios developed in the project confirms that special attention should be paid to the design and the story of these serious games. It is necessary to find a balance between the fun factor and the game's main purpose—to reduce the complexity of security and data protection issues. All the serious digital games in the project are immersive stories that depict everyday security-relevant work situations in SMEs. The players experience the stories from a first-person perspective, which is different in each game. This enables the learning content to be examined in detail and encourages identification with it.

As mentioned above, **Figure 6** (left) offers a very rough representation of the decision tree: the actual individual parts that make up the story can only be seen in the Gamebook Technology production tool. For example, decision points can be used to allow the player to interrupt the game and take a look at the glossary to get more input on the topic. Decision points may also constitute a “time choice” such that the player must choose between options within a specified period. If the player takes too much time to decide, the digital game sends them back. However, the player will retain all the information they have previously accumulated, leading to other options for the next step. This brief explanation makes it clear how important the designer's connection to the topic and empathy for the target group are in building an appropriate story.

Technical implications could be examined in more intricate detail in Dietmar Krause's smart home, which would, however, increase the complexity of the digital learning scenario. At the end of each of the three stories of the learning scenario, specific golden rules could also be presented as a watch list or made available for download. Moreover, legal implications could be dealt with in the story by Jonas Schmidt, since the AI searches his home office without consent. Further legal bases could be explored. It would also increase the complexity of the digital game.

The digital games are not a simple reflection of the analog variants because they are intended to generate independent motivation for addressing the security and protection issues. It is clear how important the designer's connection to those topics and empathy for the target group is in building an appropriate story. This means that the game designer has an important task here to develop the learning paths in an appropriate and appealing way. The more successful the designer is in this, the more the story will stick in the learner's memory. In addition, a discussion of the digital learning scenarios should take place within the company afterward—with an active, in-depth focus on IS/CS/DP debriefings to anchor what has been learned.

An analog and a digital serious game for ISA/CSA should be completed in 15 minutes, thus corresponding to the study results of [20]. The length of such a microlearning module should be very short, lasting only a few minutes: “What you can do quickly during a break” [20]. Quizzes that followed a module were also valued because they forced people to focus on content [20]. Adapting the (external) training material to the local context and language was seen as crucial by staff; however, they also acknowledged that this could be a challenge for the CISO [20]. Presentations should be limited in duration to around 15 to 20 minutes to help learners focus on the topic. Employees had a positive perception of workshops, and various types of interactive meetings in which discussions could take place and knowledge exchange was encouraged, with the element of interactivity cited as the main reason for the positive attitude [20]. We can confirm these results. Although there are similarities between the CS behavior of home users and the CS behavior of employees in an organizational context, there is a need to understand their differences and to further develop research and practice focused on the CS behavior of individuals [9].

The results of Fallahdoust indicate that individual and organizational factors influence CS behavior and, in some cases, impede secure behavior [14]. Employee understanding, gender, computer skills and prior experience, attitudes toward cybersecurity, age group, individual perception, personality type and traits, and individual perception are identified as discrete factors influencing behavior [14]. Likewise, systemic factors such as organizational culture, the clarity and transparency of communication, organizational norms and perceptions, leadership style and its reward system, and company size have an influence on employee behavior [14]. In addition, heuristics and biases influence CS behavior. Exploring the anger factor, information avoidance, and social norms as psychological barriers to CS behaviors can drive the successful implementation of policies that promote safer CS behaviors on a sustained basis. Talking about security can be successfully used based on serious games with immersive stories like those presented here. Moreover, the results show that organizational factors such as management involvement, organizational culture, and the organization’s CS norms directly influence individuals’ CS behaviors [14].

A diverse mix of different measures will be necessary to sustainably increase the ISA/CSA of all members of an organization. The framework of Eiza et al. compiles several approaches, current standards, practices, tools, and strategies that are suitable for improving CS when working from home. It also provides a common language for expressing, managing, and communicating WFH-related CS risks on the following aspects [6]:

- WFH Cyber Policies Development
- WFH Cyber Risks Identification
- WFH Cyber Risks Assessment
- WFH CS Controls
- WFH CS Monitoring
- Elimination & Recovery and Post-Incident Feedback.

Based on the experience from our project, it would make sense to prepare all these aspects in interactive, short learning scenarios that are clear and understandable, and to make them available to people working from home.

5. Summary and outlook

The final versions of the serious games on HO/WFH and mobile/remote communication presented here, like the other analog and digital learning scenarios developed in the project “ALARM information security,” will be available for noncommercial use free from the project website [61]. The development and evaluation results will be recorded in the final project documentation in German. Individual aspects will also be made available on an ongoing basis in scientific publications in English. Awareness training was carried out with different participants at a number of events. Our experience has shown that the measures and the serious games presented are very well received by the interested participants, who are keen to use them. The research team is often asked to conduct awareness training within a company or as a workshop at CS events.

Our evaluation, based on playing the serious games and interviewing participants from external SMEs, is that the project’s learning scenarios and associated games represent demanding, energizing awareness tools [60, 63]. However, no learning scenario works equally well everywhere. This means that defining an exact fit between the developed learning scenarios and their use in a particular SME is made difficult by the great cultural heterogeneity in the SME environment. To compensate for variances such that a clearly presentable, quantitative statement can be made about the compatibility of the analog learning scenarios with the corporate or security culture, the focus must be on the security awareness maturity level of the specific SME—this requires further research.

Our second study [63] suggests that a higher degree of awareness maturity in SMEs is essential for the introduction of certain learning scenarios so that the intended degree of effectiveness can be achieved. In particular, it can be assumed that gamified settings in companies with a very low level of security awareness trigger effects that are different from the originally intended prevention service. If the topic to be dealt with does not relate to operational reality—for example, if information classification is not yet a standard process in the company, or if the thematic complexity in the game is not sufficiently reduced or is too generic, this may produce more recalcitrance than positive effects. Even nudges that are frequently recommended [14] would then fail to have their potential effect.

In another task area of the project, seven “on-site attacks” are planned, which are designed, carried out, and evaluated by the subcontractor Thinking Objects in consultation with the university’s research team. These “attacks,” coordinated with the management of the companies, were, like the digital and analog learning scenarios, based on the needs of IS from the first study [56, 57] in order to raise awareness among the employees of the pilot companies of the project and to give concrete instructions for action. The particular challenge here, however, is to get the pilot companies enthusiastic about such on-site training courses, as these can disrupt the day-to-day business of the company. In addition, a special relationship of trust is required between the subcontractor and the specific SME or intensive agreements with the management and information for the employees. All pilot companies involved in this training have received a confidential evaluation of the attacks and specific instructions from the subcontractor. The following on-site attacks have been carried out so far:

- LS 1 (“Phishing”; electronic action), completed with three pilot companies
- LS 2 (“Have I Been Pwned?”/“Password Database Check”), completed with three pilot companies
- LS 3 (“Smishing”; type of attack via smartphone via SMS), analogous to LS 1
- LS 4 (“Tailgating”; physical action), completed at three pilot companies
- LS 5 (“Shutdown”; simulated ransomware attack), carried out in March 2023 with a pilot company
- LS 6 and LS 7 are planned in 2023. Information sheets, instructions, and low-threshold security concepts are created for each on-site attack; they will be published in a bundle on the project website at the end of the project in September 2023.

SMEs can be seen as the new big target for cyberattacks, while cybercrime prevention in their environment is often neglected [74]. The COVID pandemic triggered a large, sustained shift to HO/WFH, and the traditional skepticism in Germany seems to have diminished; many employees do not want to work without also working from home [75, 76]. However, the sudden shift to HO/WFH increased the opportunities for cyberattacks on individuals. According to Vakakis et al., in the future—especially with regard to the integration of IoT devices—there will be a need for more effective technical CS solutions that can be easily tailored to the evolving needs of each individual company and quickly adapted to the changing cyber-threat landscape [74]. Nevertheless, it is important to understand that the use of new technologies and new processes will not bring comprehensive security to our everyday lives, so we need to become, and remain, more careful about IS/CS [23]. IS/CS is the backbone of the successful digitization of society, and awareness of cyber situations is an essential aspect of managing them [23]. Human beings are the target of cyberattacks, but also the last line of defense, especially when technology fails.

The continuous development of ISA/CSA is an existential necessity for SMEs. Fichtenkamm et al. underline the importance of a holistic approach to awareness-raising measures, covering both personal benefits and usage in the workplace, and targeting the entire spectrum from end users to CS specialists [12]. Issues related to awareness and education are located at both the user level (in terms of lack of support) and the practitioner level (in terms of a skills shortage) [12]. It is particularly important for us to talk more about risks and IS/CS in the concrete working environment. Interactive, game-based learning scenarios with emotional design in a discursive setting covering real-life situations enable promising access to a practical exchange of experience. According to Haney et al., we need to understand that the pure transfer of knowledge in training courses is considered to have failed because the raising of awareness is about much more than knowledge [77]. For the sustainable development of a security culture in SMEs, practicable awareness measurements must also be established in the future, which will lead to statements about the degree of IS maturity of the organization. So far, however, there has been relatively little progress made in research and practice toward creating a practicable model of a security awareness maturity level for SMEs. It became evident in the course of research and during the project that awareness measurements are still an evolving field of research

and cannot be carried out for the pilot SMEs within the planned scope of the project. Further intensive research on awareness measurements and maturity statements is necessary if high-quality results are to be delivered. The conclusion we draw from this is that within the current project, we can only summarize tendencies moving in the direction of a change in consciousness. We are aiming to instigate a follow-up project that deals intensively with awareness measurements in awareness training. Such a follow-up project must be even more interdisciplinary than before because it requires far more in-depth analyses of psychology, behavioral change, and brain research.

Many organizations offer only an hour or two of knowledge training per year to raise security awareness among their employees [78]—this fails to produce any lasting knowledge, attention, or behavioral change. Instead, short, interactive game-based learning scenarios should be used continuously. Our game-based approaches instill the kind of security thinking that can turn employees into a critical layer of defense. Developing any degree of long-term effect relies on the provision of appropriate and compelling security stories that stick in the memory, as well as the opportunity for exchange between employees. The project represents a contribution to self-help for SMEs. Other service and training companies can also benefit directly from the developed materials for their own business practice. These materials can also be used in public administrations, even if some specific features of the administrations should be dealt with separately in the discursive exchange. Downloading the materials makes the results available for use; these are provided with specific instructions. The learning scenarios can be integrated into corporate practice at any time and used for training and awareness-raising purposes. However, this requires the willingness of the SMEs to do this, so the management must be convinced of the necessity. In a follow-up project, management and executives should be made aware of the need to develop a security strategy and a sustainable security culture. After the project in 2023, the awareness-raising events outlined in this paper and training courses for CISOs/ISOs [79] can be booked through the Wildau Institute for Innovative Teaching, Lifelong Learning, and Design Evaluation (WILLE), which is part of the Technology Transfer and Continuing Education Center (TWZ e.V.) at TH Wildau [80].

It should be noted that serious games are highly topical for awareness-raising measures to increase ISA/CSA and can be used successfully in a wide variety of constellations. However, they are not a surefire success; rather, they must be carefully designed and used within a practice-oriented mix for SME target groups. The awareness laboratory that has been developed is to be retained and made available to SMEs in the long term so that IS is made tangible and comprehensible as a result. It will be necessary to train moderators in SMEs so that they can establish IS as an ongoing element in their operational processes and use our developed and tested materials to carry out their own awareness-raising measures in the future. Such moderator training should be built up sustainably and possibly accompanied by a certification; this could be offered in the short term at the beginning of 2024 for a fee via the affiliated institute TWZ e.V. [80]. However, since German SMEs—and microenterprises, in particular—first need to be persuaded to make investments here, the demand must first be stimulated, and this will probably require state funds, necessarily made available via a continuous funding program.

In addition, many English-speaking employees work in German SMEs, and there are English-speaking business partners who should be involved in security issues and the development of the security culture. For this reason, the materials developed should, in principle, also be made available in English in the future. Our experiences with the pilot SMEs also suggest that in a follow-up project, the SMEs need to be specifically supported and taken by the hand in order to develop a sustainable

awareness-raising strategy and to establish continuous awareness-raising measures in the relevant business processes. In addition, based on the concrete everyday situation in SMEs with economic pressure and stress, it is to be expected that SMEs will need further assistance in order to introduce awareness-raising measures in the long term. Here, a structured and research-based approach on a systemic basis can be of great importance for SME managers in order to give SMEs the necessary assistance and to scientifically support them in their efforts. For that purpose, a third project study is planned in 2023 to provide more insight into the special needs of managers who want to build a sustainable security culture in their particular SME. Moreover, a theoretical model to elucidate the main factors involved in building the security culture is currently being developed in a second project report and will be verified as part of a third report in the period up to September 2023.

Here, it is important that ISA/CSA is not just about knowledge but also about 5 what you have learned into practice [53]. Awareness is a process that needs to be adjusted in subsequent iterations to improve its usability and long-term efficacy. The authors argue that this is only possible if an ISA/CSA program is reviewed and evaluated in a timely manner [53]. However, as there is not yet a common understanding of what factors to measure and how to measure them during the assessment process, Chaudhary et al. adapted the four indicators used in awareness assessment by the European Literacy Policy Network (impact, sustainability, accessibility, surveillance) to make it suitable for the assessment of an ISA/CSA program and to make the assessment process systematic, complete, and reproducible [53].

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Section 7

Post-Pandemic

Student Visibility and Focused Subject Interaction

Anders Øgaard

Abstract

Distance between a learner and teacher in distance teaching is theoretically confronted as a challenge in terms of contact and communication. But geographical distance does not necessarily cause mental distance. Using case studies from schools in Denmark and Greenland, this chapter proposes theoretical concepts that frame distance teaching as pedagogical development. The findings support a focus on how distance teaching stimulates a proactive learner role, and how teachers might gain from the geographical distance in terms of contact with the learners' learning and development. Teaching over distance might support an even better connection to proficiency levels and progress with the learner. Focused subject interaction and communication and enhanced student visibility are discussed as theoretical concepts for distance teaching research and practice, grounded in qualitative data.

Keywords: distance teaching theory, K–12 online learning, Greenland educational system, community of inquiry, student visibility, focused subject interaction

1. Introduction

The COVID-19 pandemic was a landmark for distance teaching development [1]. On a grim and less than preferred background, distance teaching in schools must be said to have had its finest hour, so far. But the experience for many teachers, students, and parents was a school system not prepared for elaborate use of distance teaching [2–5]. Daily improvisation by dedicated teachers became essential for school systems to continue teaching and keeping students learning and development going. The result nationally and globally has been a diverse but also a rich experience with teaching and learning.

The experience reflects a lack of dedicated and elaborate didactical concepts and terms teachers and administration can turn to when schools operate across distances. Some theoretical concepts have been coined in the field of distance teaching: *transactional distance* and the terminology of different *presences* as the most prominent. They are contested and still in process [6]. Theory exclusive to research in distance teaching still seems preliminary. And when it comes to research in K–12 distance teaching, dedicated theory is absent.

As discussed in this chapter, these theoretical concepts primarily frame distance teaching as a challenge for schools and teachers as teaching in jeopardy of missing something essential: closeness between teacher and learner. In this chapter, I will try

to show how this theoretical approach is insufficient. Contrary to the deficit framing of distance teaching and distance education, I find it relevant to look for elements of progressive pedagogical development embedded in distance teaching practice.

I will try to present preliminary theoretical perspectives: *focused interaction* and *student visibility* as relevant for researching and understanding K–12 distance teaching and distance teaching in general. These perspectives relate to autonomy, responsibility, and maturity with learners not only as a means for distance teaching but also as a learning outcome.

As part of my research in possibilities with distance teaching in the school in Greenland, I have been searching for more firm theoretical ground. The research presented in the following combines Grounded Theory from my PhD dissertation and recent qualitative studies on distance teaching in schools, in search of possible concepts and terms, which might add to the theoretical autonomy and solidity of distance teaching research and practice in schools and education.

2. Framing distance education and distance teaching

A challenge for distance teaching and distance education research is finding a standard practice to investigate. The subject includes great didactical and pedagogical diversity. Comparative case studies from Denmark and Greenland have shown how didactics found with distance teaching in schools can vary on all didactical and educational parameters, and hence be hard to perceive as a unified subject [7]. Distance teaching can be individualized, use group collaboration, or take place as classroom teaching. Time spent can be as scheduled synchronized meetings or as asynchronous flexible homework. Teaching can be divided in subjects or use extensive interdisciplinary projects. And the media use has a very wide spectrum in distance teaching, from books and assignments in paper to online learning communities collaborating through platforms and apps. On-site personal students meet also have great variety, from siblings and parents to educated teachers.

The diversity is related to the variety of educational purposes when distance teaching is chosen. Providing distance education can serve elite students striving to get ahead or maintain their social position. Distance education can also aim to provide education for all citizens, no matter where they live or their abilities to move. Practicing distance teaching comprises diverse political agendas, enhancing liberal, individualized education [8], confirming and reproducing social privileges, or carving out democracy [9] by providing access to education for more citizens.

In addition to comprising a spectrum of political agendas, distance teaching is embedded in cultural and social contexts, and sometimes encompasses dispersed and unique national locations. The inherent embeddedness of distance teaching adds to the cultural and practical diversity.

When institutions want to replace or enhance their activities through distance education, a relevant question is whether distance teaching provides the same quality as teaching in class or on campus. Following these intentions, a focus for distance teaching research has been the best practice [10]. Comparative studies establish a more clear-cut subject usable for quantitative research. But looking for the best practice substantially narrows the perspective, making it less likely to find original and unique qualities with distance teaching. The challenge of getting a scientific grip on the unique characteristics and possibilities with distance teaching is still present [11]. Research on distance teaching still seems an indistinct and fuzzy field, dominated by

search for instructional advice, learner satisfaction, best practice, and applicability of distance teaching [12].

The conclusion is that the field still needs open questions. We still need to ask what a distance between the teacher and learner means in terms of literacy, competencies, the fabrication of knowledge, identity development, inclusion, etc. What relations and roles are provided with distance teaching? What kind of behavior and conduct is learned? How is subject matter shaped in this kind of setting? What is at stake with distance teaching?

In 1993, researchers in the field joined forces in an attempt to establish a more solid theoretical foundation for research and practice in distance teaching and distance education. The anthology *Theoretical Principles of Distance Education* [13] was written just before the internet started working its way into teaching and education, and into society in general. The anthology expressed expectations for a paradigmatic change away from distance education as comparable to industrial production [14], merely providing access for the masses to knowledge and exams, toward distance education embracing pedagogical development. The framing was expected to change from distance education as an individualized endeavor for diplomas (later named *mass-individualization* by Francis Lee [8]) to distance teaching exploring two-way communication, creating learning environments, and drawing on collaboration [15, 16]. The paradigmatic change anticipated in the anthology from 1993 has been fueled by the expansion of digital technology and the advent of the internet. The transformation of distance teaching and education toward pedagogical development needs more theoretical backup and underpinning. The guiding research question in the following is how to describe distance teaching in theoretical terms comprising pedagogical development. Before I go into methods and suggestions for theoretical terms, I will shortly go give a critical discussion of prevalent theory and terms in the field of distance teaching and distance education.

3. The distance in distance teaching

A widespread and recognized theoretical perspective for studying distance teaching is *transactional distance* [10, 17]. Transactional distance describes the interaction between teacher and learner in a learning environment where they are geographically separated. The perspective is presented in the anthology from 1993 and was developed by Michael G. Moore [18, 19]. According to Moore the combination of fixed educational structures and little dialog with a teacher transforms to distance in the teaching setup. Distance teaching with less dialog and thus greater transactional distance demands learners to display autonomy. More dialog and more organizational flexibility mean less transactional distance, and hence require less autonomy from the learner [18].

It seems relevant to relate distance to educational structures and dialog between teacher and learner seems relevant. But the relation proposed by Moore is worthy of critical scrutiny. Autonomy for the learner is considered a prerequisite for highly structured teaching. However, highly structured teaching, for example with fixed learning goals, leaves little space for unfolding and developing autonomy. Conversely, looser structured teaching is considered adequate for students showing less autonomy. But looser structures require greater self-management and require students who are ready to show self-reliance and maturity. In the same vein, the theory opposes autonomy and self-management with dialog with the teacher. However, most educators will have experienced how contact with mature and autonomous students easily

causes a lot of dialog, just as contact with less mature students may lead to less dialog. The a priori correlation between more structure, more dialog, and less autonomy from students needs data and a more thorough and nuanced examination.

But more important is what makes the concept exclusive for distance teaching and distance education. The concept of transactional distance is about structure and dialog related to learner autonomy. But relations between structure, dialog, and learner autonomy are relevant considerations with all teaching and educational activity. Attending campus, auditoriums, and classrooms can just as well be an experience of educational distance. I need an argument for why these considerations change because of the geographical separation of teacher and learner. The theory implies a connection between geographical distance and psychological distance, but it appears as theoretical speculation [20].

Another widespread theory developed for distance teaching research is a terminology comprising various forms of presence [21]. According to this theory, presence in distance teaching can be analyzed in three forms: social presence, cognitive presence, and teaching presence [22, 23]. Cognitive presence describes learners' possibilities to interact with the content. Teaching presence captures the presence of didactical structures with the learner. Social presence is the essential concept, and it can be described as the degree of being personally present in a distance teaching situation. Teaching presence conceptualizes learners' possibilities for projecting their personality into a learning environment and connecting with a learning environment across distance [24]. Though the different kinds of presence seem relatively definable, there is considerable ongoing debate about defining especially the term *social presence* [6]. A question is how broad this term should be defined, also comprising normative aspects as intimacy, social respect and recognition, student satisfaction, and more structural questions about immediacy of feedback and contact.

Following the paradigmatic change predicted in the anthology *Theoretical Principles of Distance Education* [13] Randy Garrison combines the *presence* perspective with learning communities as a progressive framing of distance teaching activity [13, 23]. Inspiration comes from John Dewey's concept of learning as reflective investigative processes [23, 25] and from Vygotsky's cognitive learning psychology [23, 26].

According to Garrison, communities of inquiry (CoI) is a potent structure to follow for digitally supported distance teaching [23]. Communities of inquiry is suggested as distance teaching providing a high amount of presence [27]. Fueling distance teaching toward progressive pedagogical change and development is the advent of digital technology supporting dialog and collaborative learning environments across distance [16, 23, 28].

Questioning presence in teaching situations, especially when suggesting learning communities, seems a relevant focus for research in distance teaching and education. But as with Moores concept of transactional distance the exclusive relevance for distance teaching research is not obvious.

When questioning presence in distance teaching and distance education, the theory is based on the assumption, that physical presence provides optimal conditions for communication and contact between people. However, conventional classroom teaching can be a lonely and isolating experience for learners, comprising the absence of relevant content, the absence of meaningful structures, and the absence of contact with teacher and fellow students.

I find a lack of argumentation for why reflective investigation (Dewey) and social interaction (Vygotsky) should become weaker, when the teacher and learner are geographically separated. Engaging with subject matter (cognitive presence), the

presence of didactical structures (teaching presence) and projecting oneself into learning communities (social presence) seem as relevant and challenging for distance teaching as for all educational activity. It all depends on the kind of teaching teacher and the institution provides, regardless of physical attendance or spatial separation. The question of presence is about the quality of teaching and the quality of an educational institution, not necessarily about geographical distance.

The concept of the different presences frames distance teaching as an activity where contact with the learner is in jeopardy. There is documentation that school students taking part in distance teaching can feel a lack of community, a lack of social interaction, and feel isolated [26, 29]. Thus, the lack of presence can be an issue with distance teaching. But presence is not an essential condition for distance teaching to work. The definition of previous distance education as individualized [8] and industrialized teaching [14] does not define distance teaching as a question of presence, but as a question of autonomy at the students part.

The concept of transactional distance and the different terms of presences is well-established theory in the field of distance teaching research, but framing the phenomena as teaching lacking something essential to teaching is a dead end. Where media are needed because of physical separation, the theories propose harder conditions for communication and presence. But this is an assumption that needs documentation and theoretical clarification. Distance teaching might as well pave way for new educational shapes of presence and contact [7, 9, 23, 30]. This is what Garrison engages in, when he considers how distance teaching can be an advanced alternative to the conventional classroom by being organized as participation in collaborative communities, demanding presence from everyone involved to work [23].

4. Ontological considerations

The anthology *Theoretical Principles of Distance Education* from 1993 left a gap in terms of theory on distance teaching with schoolchildren [15]. Theory-devoted K–12 distance teaching is still in demand. Lokey-Vega et al. [10] go as far as calling out a theoretical crisis for research on K-12 distance teaching. Attention has been on adult education, as exemplified by Peters [14] and Lee [8]. Teaching at distance is connected to adult education, almost by definition [18].

This firm framing of distance teaching as adult education might be indicative of what is defining for distance teaching. Otto Peters pointed to the necessity for learners in distance education to take responsibility for their own learning, and the necessity of developing self-determination, self-direction, and self-control [31]. The prototype learner in distance education is expected to be able to operate without disciplinary surveillance in a learning environment demanding independency and maturity. This could leave out children as students. However, schools in Western countries have used distance teaching for about 100 years [32–34], in many places to a large extent. And COVID-19 forced thousands of schools to operate through distance teaching for a substantial time period. Teaching can be defined as a person taking responsibility for another person's learning and taking responsibility for giving learning processes an intended direction, aiming for certain learning goals [35]. Education is, by definition, a guided activity with a defined learning purpose [23]. Watching lectures or tutorials on YouTube or reading books or manuals on your own is excluded as teaching from this definition. It might be learning, but the defining component for teaching is someone else taking responsibility for your learning, and engaging in your development,

with intentional goals in mind. Distance teaching can be defined as someone taking responsibility for another person's learning from a distant location.

Following this definition, a teacher responsible for each learners' activities and progress is integrated in distance teaching. This definition explains why distance teaching has been possible with schoolchildren despite the demand for autonomy and self-reliance. There is, by definition, a supporting and responsible person involved when teaching. Autonomy is always balanced by cooperation with a teacher.

What the dominant focus on adult education reveals is a certain student role connected to teaching at distance. Otto Peters connected maturity to distance education not only as an a priori precondition with the learner, but also as a learning outcome. Learners in distance teaching have to behave proactively. In contrast, the physical presence behind school desks, in auditoriums and classrooms and in corridors and school halls, is accepted as the presence in brick-and-mortar schooling and education. But without support from physical structures, distance teaching requires another form of attendance. The learner is not supported by physical presence and has to be active. Without proactive students, distance teaching will dissolve and disappear.

Professor Norm Friesen from Boise University in the USA has described how digital online distance teaching is demanding activity:

By requiring users to log on, to click here versus there, to choose some words but not others in composing and submitting explicit communications, Web technologies repeatedly foreground explicit action over inaction. ([36], p. 158)

This brings Friesen to the conclusion that distance teaching using digital online platforms demands proactive student behavior:

Online experience unfolds in locations in which silences associated with stasis and rest is rendered problematic, and in which it is not possible or easy to distinguish between passive presence and the simple probability of absence. ([36], p. 158)

Solid and reliable participation from the learner seems to become crucial for educational activity across distance. Cavanaugh et al. propose that digital learning engages teachers, as well as learners, in transparent collaborative reflections on learning and progress, empowering learners to be part of teaching and education in a much more responsible and active way [28]. Outlining benefits of online education, Boboc also points to a next generation of learners embedded in distance teaching in schools [37].

Research presented in the following shows how mediated communication is supportive of teaching activities to a degree, where teaching at distance seems to potentially outdo classrooms and auditoriums in terms of producing visible and mature students.

5. Building new theory for distance teaching research

The following presents preliminary results from a research process initiated with my PhD dissertation from 2015 [38]. The dissertation was a study of possibilities with distance teaching in a school in Greenland. As a method for getting more firm theoretical ground to work from Grounded Theory was applied. Grounded Theory is an iterative process laboriously extracting new concepts and terms from gathering and interpreting empirical material: creating theory from the ground [39]. The

developers, Barney G. Glaser and Anselm L. Strauss, contested the idea that research should be confined by current terms and concepts and advocated for creativity on behalf of researchers. According to Glaser and Strauss, new terms and concepts can perfectly be the primary objective for research ([29], p. 18).

The qualitative method of digging for theory has been criticized for expecting new terms and concepts to emerge from data by itself [40, 41]. Following a hermeneutic tradition, no a priori interpretation is possible, and new theory will always be framed by established consumptions. Glaser and Strauss confronted this methodological challenge when they developed Grounded Theory. Their solution was to develop a systematic method, where articulations, terms, and concepts from the field, as well as from researchers, integrate in an iterative creative process ([39], p. 253). In parallel with the data collection process, findings are summarized in applicable but always provisional terms and concepts. This clarification unlocks the hermeneutic restraint on working with data when developing a new theory. The decisive question for Glaser and Strauss was whether a systematic and thorough method was employed, and the iterative process sustained long enough for new concepts to emerge in the process.

6. Empirical work and data

According to Glaser and Strauss, a variety of data is pivotal for challenging established concepts and perspectives, and to feed the creative process toward new concepts. For the Grounded Theory presented in this chapter, a wide variety of empirical material has been used. Part of this work is presented and discussed more thoroughly in my PhD dissertation [38]. Open focus group interviews have been conducted with teachers, students, parents, and administrators in different combinations.

I have made observations in schools, looking at distance teaching activities, as well as observing everyday routines, where distance teaching took place. I looked at products and assignments made by students. A useful method for data collecting has been utilizing tablets (iPads) students and teachers used for communication and production purposes. Activities and traffic have been recorded and stored, which have provided a unique look into teaching and learning during the course of the cases.

Documents and reports from consultants and administrators have also been included. This data is mostly relevant for analyzing discursive positions and can be misleading when looking for concepts grounded in practice. Where documents and reports have been valuable, is when elements of evaluation and case presentation have been documented.

A recurring circumstance is that informants relate distance teaching to conventional teaching. This is in line with the general construct and discourse of distance teaching. Assessing the quality of providing access to a conventional teaching setting is the backdrop when discussing distance teaching. In the interviews, this tendency has required guided comparisons to support the process of connecting different and new words and concepts to distance teaching practice.

From this diversity of qualitative data, it is possible to discern teaching patterns and conditions that define distance teaching. The creative next step is to articulate and choose words and concepts that seem to be connected to or cling to the research object.

A premise for this work has been that data exclusively comes from distance teaching in schools. And data only come from Greenland and Denmark. The applicability of the resulting theory to other groups of learners, to other parts of the educational system, and to other countries calls for more research thorough considerations and

discussions, which lie outside of this chapter. For now, I rely on the theoretical discussion above that distance teaching as such can be comprehended and discussed across sections, and that there are theoretical commonalities to be found.

7. Focused and transparent subject interaction

I now turn to the data analysis. A case study from my PhD dissertation exposed relations and contact between teachers and their distance students. The study is from distance teaching in a small settlement in Greenland [7, 38]. The settlement had a school building and schoolchildren, but no teachers. Distance teaching was implemented from the municipality in 2010 to serve all subjects and all teaching. The students experienced distance teaching as individual activities in a classroom with a teacher giving instructions from an online screen. The teachers were aiming for conventional teaching.

A schoolgirl in this case study experienced how the teachers wanted her to be more explicit in her communication. She communicated mainly by moving her eyebrows or wrinkling her nose, which is common way of expressing “yes” and “no” in Greenland. Although the teachers were Greenlanders, the girls’ sparse communication was not satisfying for them, and they asked the girl to communicate more explicitly. The distance teaching situation demanded this student to be more talkative and engage more in the teaching situation, which she quickly learned to the teachers’ satisfaction.

In an interview with one of the students and his mother, who had moved from the village and now lived in the city, the boy and the mother reflected on the teaching experience in the village. In comparison, the boy experienced much more random and insecure attention from teachers in the town school than he had experienced in the settlement from the distance teachers. According to the boy and his mother, the distance teachers had a very exact feeling of his progress, and they followed him closely. The boy and his mother reported a decline in the boy’s skills after he left the distance teaching and moved to the town school.

The closer contact with the boy’s progress and development could be explained by the much lower teacher-student ratio in the distance teaching situation. It was clear from the interviews that this low ratio provided the boy with teacher attention. But the teachers were at the same time enrolled as ordinary teachers at the town school, which put a limit to the amount of extra attention they could give to their distance students. The case is about teachers showing good contact with student progress in a distance situation.

A second relevant case study from my dissertation is from a school project that ran over the course of a few weeks across three small schools in Denmark in 2012 ([38], p. 72). Distance teaching in this case differs in every aspect from the distance teaching in the small settlement in Greenland. For a limited period, the students engaged in communities of inquiry under the headline leisure time activities. Students formed groups across grades and across schools, and teachers were appointed supervisors, also across participating schools. The subject was English. The assignment for the schoolchildren was to form associations about interests they shared in each group. Associations were formed for angling, pets, computers, etc. All written communication had to be in English.

The geographic separation supported communication between students and teachers: explicit exchange of tasks, assignments, questions, and answers became necessary.

The teachers reported in interviews how the use of media provided opportunities for detailed and focused support and instruction. Contact through media added transparency to the learning processes their students were engaged in.

Teachers agreed in interviews that the distance teaching brought them in closer contact with the progress and development of their students than they were used to in the classroom. The teachers experienced exceptional professional contact and communication with their students. Some teachers valued that for this reason, they might even prefer distance teaching to conventional teaching.

A third case study is from another small village school in Greenland. This study was conducted in 2016 and not part of my PhD dissertation. Again, the distance teaching differs in every aspect. For half a year, schoolchildren at all levels had regular individual conversations with an English-speaking teacher in Kenya. The distance teacher did not speak Greenlandic, and this way, the schoolchildren were forced to develop skills in spoken English. The conversations were held with headphones one on one in a quiet corner of the small school building. Occasionally, teachers or other students would join in to help with translation or supply with English vocabulary. The distance teacher made notes on the schoolchildrens' interests and on their progress and shared her observations with the teachers in the village. Together, they decided on subjects for the conversations and how to support the students' progress.

These weekly conversations typically lasted from 5 to 10 minutes. The distance teacher was very confident that these short but regular conversations were enough to generate good progress for her students. This was also the experience that the teachers in the village had.

The method used by the distance teacher in Kenya was to establish a personal relationship with each student, and let the personal contact guide the way to better language skills. She did not want her students to experience the sessions as teaching but as friendly conversations.

The short friendly meetings were concentrated, and the contact immediately focused on English dialog. The devoted contact made the contact between teacher and student transparent, which is reflected in the distance teachers' observations and reports being in line with observations made by the teachers at the village school. The distance supported personalized contact, and made communication and meetings between teachers and students concentrated, focused, and transparent, and thus, the distance gave the teacher in Kenya effective and sufficient tools for her English teaching.

The final case study, I include showing focused and transparent subject interaction is a research project on distance teaching in crafting and design from 2019, again from a small village school in Greenland. In this distance teaching, an important part of the teaching subject was bodily embedded competencies and skills for woodworking. An interest with this research was to see how distance teaching conveys this type of content.

Schoolchildren in seventh grade in a small and isolated settlement were taught crafting and design for one and a half hours once a week by a teacher situated in a town school. The students shared three iPads devoted to contact and communication for the distance teaching lessons. The lessons began with the students fetching the iPads and the tools, going to the workshop, and collectively making a call to their distance teacher. The teacher instructed the class together. During lessons, there was an open synchronous call. Whenever the students had a question or wanted feedback on their progress, they went to the tablet and had a short dialog with the distance teacher, and then carried on with their design. The teacher also commented and adjusted their use of tools through the iPad call. The synchronous contact with the teacher was combined with dissemination of subject matter through instructional

video clips on their iPads made by the teacher in advance. In Greenlandic, he instructed the correct use of different tools. Each weekly session was rounded up with an online evaluation of each student's individual work, followed by the students tidying and sweeping the workshop on their own.

The teaching in these case studies differs in many aspects. Together, they show a great didactical diversity. What they share is the geographical separation of teacher and learner. The geographical separation framed communication and contact in ways that supported firm and detailed focus on the subject matter. The interaction and communication between the teacher and students were focused and relevant. The separation brought transparency to the interaction so the teachers all experienced a satisfying connection to their students' progress and development. In these cases geographical separation made the teaching go through different media which came to function as magnifying devices.

8. Student maturity connected to distance teaching

I now turn to a related theoretical perspective relevant for distance teaching research. Focused and transparent interaction seems connected to a certain way of taking part as a student in distance teaching. As mentioned, engaging in teaching and education at a distance is associated with adult education. It is expected that students are able to operate on their own without surveillance. A mature and proactive learner role might be closely connected to distance teaching.

Starting with the case study on the school project leisure time activities from island schools in Denmark, the teachers reported a rare level of productivity and engagement from students. They had never seen specific students write as much before, and even in a foreign language new to some of them. A problem the teachers usually dealt with was students being kept dependent on their help. The teachers explained that the safe and intimate learning environment in small island schools made it too easy for school-children to ask for help from their teachers and too enticing for teachers to help. The distance teaching situation demanded the students to be self-reliant.

In interviews, students reflected how the separation from the teachers inspired them to be productive. They exemplified with the necessity of helping each other to develop a functional written English, so they could work together across distance on their association about their favorite leisure time activity.

Students reflected in a group interview on the freedom, power and control they experienced that they were entrusted with in the distance teaching situation. They were aware that they could turn off the internet connection at any time (in fact, turn off their teacher) and be left alone to do whatever they pleased. This freedom was a bit worrying to some of them. They discussed the limits of schooling, and at what point teaching and learning would dissolve from too much flexibility and freedom. They felt there would come a point, where distance teaching would be too demanding, when it would be too hard for them to show the self-discipline they felt was necessary for their learning ([38], p. 77).

In another interview with students, the debate also revolved around the limits of adult presence for sustaining order and discipline. They wondered if a robot present with them would put a limit on conflicts and gaming. A robot would not be enough they concluded. The demand was contact with a real person if the distance teaching situation was to make sense for them. They had to feel responsible to a real person they knew ([38], p. 80).

What stood out from these interviews was how the students reflected on their responsibility for the teaching to work. It was obvious to them that the distance teaching gave them real responsibility, and that it was more demanding in terms of autonomy, self-reliance, and cooperation. These considerations were reflected by both teachers and students. They all experienced how the students matured and rapidly became able to cope with the demanding teaching situation.

The same experience of maturity and responsibility on the part of the learners was found in the case study from a municipality solution with distance teaching in a small settlement in Greenland. The boy became very involved in the distance teaching to a point where it caused him trouble. The pedagogy chosen by the teachers and the administration was not progressive, and the teachers did not want the boy to “take over the teaching” as they expressed it. He was proactive to the extent that the teachers became insecure and reprimanded him, though it is clear from interviews that his intentions were good, and his behavior was constructive and supportive. Although the teachers strived for firm control, the distance teaching situation stimulated this student to show independence and be proactive, and challenge the conventional didactical design.

Student maturity was also a theme in the second case from Greenland, where the school had an English teacher from Kenya. When calling up on Skype, the distance teacher was very careful to make the student lead the conversation. In advance, each student prepared by making drawings or collecting personal items to show their distance teacher in Kenya. It was very clear from observations, footage from iPads, and interviews with teachers that students of all ages and at all levels reacted with engagement and responsibility to the preparation their teacher in Kenya demanded from them. Sometimes their conversation would turn around, and the student would take over as teacher, teaching the Kenyan woman Greenlandic or informing her about their everyday life in Greenland. The conversations became a platform for the students to be proactive, and a platform for growing responsibility for their own learning.

The teachers in the village saw personal confidence as a very important part of developing oral English skills with their children. Talking in a foreign language with a person from outside, the village can be demanding and transgressive for Greenlandic children. But the experience in this case study was that distance teaching provided a safe and inspirational platform for schoolchildren at all levels to engage in developing their English skills.

The teenage girl in the village school reported how she found a personal friend in the young African woman. Their conversations became a platform for private talks and personal development, away from the teachers’ omnipresent attention in the small village school. The teachers in the village experienced how the girl surpassed the oral skills of her Greenlandic English teacher. The regular contact with a remote native speaker was very productive for the teenage girl’s skills and maturation.

Maturity was also evident in the case study on crafting and design from 2019. When the distance teaching was launched, observations found how the distance teacher felt safe after just a short time of instruction and dialog to challenge his distance students’ discipline. He turned off the online contact for short periods of time, leaving the students from sixth and seventh grade on their own in the workshop with the assignments and the woodworking tools. The students continued focusing on the assignment given by their distance teacher and kept the lessons going by themselves.

To start off the distance teaching, the schoolchildrens new remote teacher gave them detailed design plans to follow. They followed their distance teacher’s instructions precisely to a finished product. After a couple of runs with premade designs, the distance teacher was confident that his remote students were able to handle more

open and individual designs. He gave a more open frame for activities, letting his students work on their own boat designs.

Observations and video footage found schoolchildren engaging in woodworking. Assignments and instructions from the distance teacher were obviously clearly communicated. The students copied what they saw on the premade video clips, got feedback from their distance teacher, and combined the information with trial and error, often in collaboration. Observations showed how the schoolchildren in the village adapted correct and disciplined use of woodworking tools and use of a workshop, and developed competencies to follow a design, and to work out their own designs.

The distance teacher felt he knew each one of them to the extent that he had no problem relying on their self-management. He experienced that he had a better impression of skills, interests, and progress with his distance students in the settlement than he had with his students in the workshop at his school. He explained that part of this came from his distance students being very active and engaged in his crafting and design lessons. The teacher found his distance students to be very visible to him. The student's maturity was exemplified by one of the students creating an iPad stand out of wood. On his own initiative, the boy wanted to support the communication with their distance teacher. Communication and visibility seemed to become a shared responsibility in the distance teaching situation. The freedom and the need for collaboration on making the distance teaching situation work were met with responsibility, and hence visibility from the Greenlandic schoolchildren in the settlement. The distance teacher expressed how he did not consider mediated contact a problem or a challenge but as a supportive element in his crafting and design teaching.

The case study about the project work leisure time activities from Denmark showed how distance teaching can also be vulnerable. One student reported how all his communication in English was made from copy-pasting. To his amazement, his distance teacher did not detect this. For the distance teacher, this student was invisible. This did not bother the boy; he was happy to get through the school project without making much effort. He did not sense how he was responsible for being visible for the distance teaching to work.

This instance reveals how it is pivotal that students take steps to become visible if distance teaching is supposed to work. Teachers also sense the necessity of student visibility. Hiding is made easy with distance teaching, but as the case studies show, schoolchildren tend to be aware of this and tend to take responsibility for being present and visible. The case studies show a connection between distance teaching and student responsibility for the teaching to work, and a decisive part of this is students becoming and staying visible for their distance teacher.

9. Discussion

Otto Peters described distance education as modern rationalization, effectively distributing more standard education to more people. His critic though relevant miss the didactical possibilities also part of the same rationalization and effectivization. The different case studies showed distance teaching as supportive of teachers' contact with their students. Spatial separation of learner and teacher necessitates use of media and contact through media seems to concentrate and focus contact and interaction.

The first theoretical concept I will suggest for distance teaching research is focused and transparent subject interaction. It seems relevant to look into how separation exposes learning and brings teachers in contact with learning processes.

Theories framing distance teaching with the terms *distance* and *presences* assume geographical distance will provide challenging teaching situations. Distance/presence theory produces research questions basically asking to what extent distance teaching feels distant for the learner, which is relevant in some cases, but not enough to understand and grasp the diversity and changing development of distance teaching. In times of transition to new media culture concern about what might get lost is expected, in this case, social presence in teaching. However, this line of thought blocks the possibility that teaching across distance can bring changes that enhance contact, communication, and relevant learning. Results coming from the COVID-19 lockdown also show new kinds of contact, communication, and collaboration [42], which theoretical concepts should be able to grasp.

A second theoretical focus I will suggest is how distance teaching promotes certain learning. An undercurrent of differentiated maturation seems to be integrated into distance teaching. In the case studies, the necessity of focused and transparent communication brought teachers and learners close together on the assignment of learning. Geographic separation supports sharing of responsibility between the teacher and students. Students in these cases typically felt and understood the demand for being proactive and visible for the distance teaching to work. The distance in distance teaching seems to encourage students to become professional students.

In an interview from the case study from Denmark, the notion of schoolchildren as professional students came to one of the headteachers mind. The term stems from the Norwegian professor in psychology Ivar Bjørgen (*Ansvar for egen læring*, AFEL: responsibility for own learning [own translation]) [43]. In pursuit of infusing school with meaning and necessity, Bjørgen suggests that students experience real responsibility. Bjørgen follows a tradition for progressive pedagogy, and his interest is a new learner role related to cultural changes in society toward equality and democracy. According to Bjørgen responsibility for own learning will engage students as professional students, which will develop relevant and contemporary skills and competencies [43].

Garrison explores similar contemporary changes with the learner role [23]. Garrison connects distance teaching and teaching as communities of inquiry (COIs). When teaching is about engaging in collaborative inquiries, teacher and student responsibilities and roles are shared and exchanged. For Garrison, COIs are a path to follow for elaborating on possibilities and potentials with distance teaching ([23], p. 23). When Garrison is connecting distance teaching to communities of inquiry, it is indicative of the progressive potentials imbedded in the distance.

On discussing the phenomenon of blended learning, Garrison arrives at the conclusion that distance teaching might be absorbed into conventional education for its benefits and pedagogical potentials, and disappear as a distinctive category ([23], p. 107). Communicating through email, SMS, social media, online platforms, learning management systems (LMSs), etc., is already integrated in most educational activities. Professor in public education Gert Biesta has made the same point [44]. In Denmark, the term hybrid school has been suggested by Sørensen and Levinsen [45]. They define the term as how school is already taking place in virtual spaces, as well as in real life. The combination of face-to-face meetings and omnipresent asynchronous contact through writing is becoming the norm.

In time, digital technology and rationalizations might make distance obsolete. Teaching will exploit the flexible potentials and gains in terms of learning and literacy, utilizing various forms of contact (polysynchronous dialog [46]) without hesitation. Theoretical attention to distance teaching might even be misleading,

prescribing a challenge, where these case studies showed distance teaching as a solution to disengaging and anonymous teaching in classrooms and auditoriums.

The potentials for pedagogical development from distance teaching seems obvious. However, there is a call for persistent theoretical development with sufficient openness to breed new knowledge and understanding if the potentials are to be explored [1].

Theoretical tools to describe and understand distance teaching on its own terms are needed. The concepts proposed need more research in terms of imbedded values and normativity. A question is also to what extent focused and transparent subject interaction and student maturity are norms that can be found with adolescence and adults as learners, as well as in other cultural contexts than Greenland and Denmark.

10. Conclusion

Theories are tools for developing relevant and precise research questions. The presumption with theoretical concepts such as transactional distance and social presence is that media subtracts from the ideal communication situation, which is when teacher and learner share the same locality. Following the analysis in this chapter, it seems more relevant to ask how spatial separation and media dependency in teaching also can qualify and enhance communication and contact. Distance might be defined for distance teaching, but not necessarily as weaker contact between teacher and learner.

What the various case studies on distance teaching in schools have shown is how K–12 distance teaching can produce visible students. Not as persons the teacher can smell and pat on the back, but visible as individuals on learning paths. The distance gives teachers tools to look into students' progress. Connected to student visibility is strengthened subject interaction. When the teacher and student had contact in the case studies, focus on the subject matter was immediate. Distance teaching supports focused interaction between the teacher and the learner. Based on the case studies, I suggest more attention is devoted connections between distance teaching and focused and transparent subject interaction.

This perspective on distance teaching is related to learners as proactive and professional students, which seems to be a fundamental component with distance teaching. The separation can cultivate a certain learner conduct. The separation of teacher and learner might be supportive of relevant learning processes in contemporary society.


Crisis situations from climate changes and the decline in biodiversity will become more frequent, and teaching and education will need to adapt to isolation and less mobility. In this cultural situation, distance teaching might be a main solution for the national educational systems. Gradually, new generations might adapt a more proactive and self-reliant learner role, designed to engage in an enhanced level of lifelong learning in a dynamic and changing society.

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Mathematics Enrichment through Accelerated Learning to Mitigate Learning Loss due to COVID-19 Pandemic and Distance Learning

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Abstract

The COVID-19 pandemic caused a social and economic disruption around the globe. This affected 90% of the world's school children and caused the shutdown of schools in more than 190 countries; in the US, the school closure of K – 12 schools affected 55.1 million students in 124,000 public and private schools during the 2019–2020 academic year. This caused a transition to virtual/remote teaching and learning with little or no preparation for teachers and students. K-12 school enrollment dropped by 2.9 million from 2019 to 2020, widening pre-existing disparities in access and technological opportunities. Students in high-poverty schools were hit hardest in areas of math and reading. Black and Latino students lost 6 months in math compared to their counterparts. This has resulted in a lot of “unfinished learning” from the past years. The latest NAEP results show that on average, nationwide math and reading scores for thirteen-year-olds are the lowest in decades. Due to the pandemic, today's students may earn \$49,000 to \$61,000 less over their lifetime when they enter the workforce, and this could cost the US economy \$128 billion to \$188 billion every year especially because they lack the skills, behaviors, and mindset to succeed in their workplaces.

Keywords: accelerated learning, personalized learning, mathematics enrichment, E-learning, unfinished learning, learning loss

1. Introduction

The global COVID-19 pandemic has caused significant disruptions to the traditional education systems that have long been in place [1–3]. Schools and educational institutions worldwide have had to swiftly adjust their methods of teaching and learning to adapt to the challenges posed by remote and online education [4]. However, while the pandemic has undoubtedly presented numerous hurdles, it has also provided a unique opportunity to reevaluate and reimagine education as we know it [5]. In the face of these unprecedented circumstances, educators and policymakers

have been compelled to think innovatively and embrace alternative modes of education delivery [6]. The sudden shift to remote learning has forced a reexamination of traditional teaching practices and prompted a greater exploration of the potential of e-learning, creativity, and technology. As a result, this crisis has opened up new possibilities and pathways for transforming education [7]. This chapter delves into the transformative power of e-learning, creativity, and technology in shaping the future of education in the post-pandemic era. By harnessing these elements, education can become more inclusive, flexible, and student-centered. E-learning, which has become a cornerstone of remote education, offers unique advantages in terms of accessibility, flexibility, and personalized learning experiences. Students from diverse backgrounds and geographical locations can access educational resources and participate in interactive online classes, transcending the limitations of traditional classroom settings. Moreover, this crisis has underscored the importance of fostering creativity in education [8]. Creativity nurtures critical thinking, problem-solving, and innovation, which are essential skills for the future. Integrating creative approaches into the curriculum can empower students to think outside the box, explore diverse perspectives, and develop imaginative solutions. By encouraging project-based learning, design thinking, and arts integration, educators can cultivate an environment that nurtures creativity and fosters a growth mindset among students [9]. Technology has emerged as a pivotal tool in transforming education during this crisis. The integration of technology in learning environments offers a wide range of benefits. Learning management systems (LMS) streamline content delivery, assessment, and communication between teachers and students. Virtual reality (VR) and augmented reality (AR) provide immersive experiences that enhance understanding and engagement. Gamification and game-based learning make education more interactive and enjoyable, while data analytics and adaptive learning systems personalize instruction based on individual student needs [10].

In accelerated education, the physical learning spaces must also be reconsidered [11]. Flexible and adaptable learning environments that accommodate both in-person and online learning are essential. Redesigning classrooms to promote collaboration, creativity, and active student engagement can enhance the learning experience [12]. Outdoor and community-based learning experiences can connect education with the real world, fostering experiential and holistic development [13]. Accelerated education also requires empowering educators with the necessary skills and support. Continuous professional development programs should equip teachers with the knowledge and expertise to effectively integrate e-learning, creativity, and technology into their teaching practices. Teachers must embrace their roles as facilitators, guides, and mentors, fostering critical thinking and nurturing creativity among their students. Collaboration among educators through professional learning communities can create a dynamic environment that encourages innovation and growth [14].

Furthermore, the post-pandemic era calls for a renewed focus on equity [15] and inclusion in education [16]. Efforts must be made to bridge the digital divide and ensure equitable access to technology and online resources for all students [17]. Universal Design for Learning (UDL) should be implemented to accommodate diverse learning needs [18–20]. Culturally responsive pedagogy and inclusive digital content can create a learning environment that embraces diversity and promotes inclusivity. As assessment practices evolve, a shift towards holistic and authentic evaluation methods is necessary [21]. Competency-based assessment, portfolios, multimedia presentations, and continuous feedback can provide a comprehensive view of student learning, focusing on skills, application, and problem-solving abilities [22].

Ethical considerations and digital citizenship are crucial aspects of education in the digital age. Responsible technology use, media literacy, and digital well-being should be taught to students to ensure their responsible engagement with technology and the online world [23]. Technology enables global connections and collaborations. Virtual exchanges, interdisciplinary learning, and global resource sharing expose students to diverse perspectives, promote intercultural understanding, and foster a global mindset [24]. By leveraging these tools and approaches, we can create a more inclusive, flexible, and student-centered education system [25].

2. The rise of E-learning

The pandemic has accelerated the adoption of e-learning, causing a profound shift in education. This rise of e-learning has triggered transformative changes with wide-ranging effects on students, educators, and the educational system [26]. The pandemic catalyzed the acceleration of education, embracing technology, and fostering a more flexible and inclusive approach to learning [27]. The implications of this shift are substantial and can potentially reshape the future of education in a profound and meaningful way. The three aspects we will discuss are as follows: expanding education access through increasing accessibility and flexibility, increasing access to personalized learning, and providing more opportunities for student collaboration and engagement.

2.1 Accessible and flexible access to education

Traditional education often faces challenges related to geographical location and socioeconomic status, and E-learning has revolutionized the accessibility and flexibility of education [28]. Students in remote areas or underserved communities may often have limited access to quality educational institutions. However, e-learning can bridge this gap by providing equitable access to education [29]. With a computer or mobile device, and an internet connection, students can access educational resources and participate in online classes anytime and anywhere. Reducing physical boundaries with more access and increased flexibility ensures that education is no longer limited and creates more significant opportunities for students who may have been previously disadvantaged [30].

E-learning offers unparalleled flexibility in time, pace, and learning modalities. Traditional education typically follows fixed schedules, with students required to be physically present in classrooms at specific times. However, e-learning allows students to learn at their own pace and in their preferred environment. Students can choose when and where to engage in learning activities, accommodating their preferences, personal obligations, or other commitments. This flexibility empowers students to take control of their learning journey and customize their educational experiences to suit their specific needs [28].

2.2 Personalized learning

Another significant benefit of e-learning is its capacity for personalized learning [31]. E-learning platforms often incorporate adaptive learning technologies that tailor instructional content and assessments to each student's individual needs and abilities [32]. By analyzing data on student performance and learning patterns, these platforms

can provide personalized recommendations, adaptive exercises, and targeted feedback, enabling students to focus on areas where they need additional support and challenge themselves where they excel. This personalized approach enhances learning outcomes, as students receive tailored instruction that meets their unique requirements, ultimately promoting more profound understanding and knowledge retention [33].

2.3 More opportunities for students' collaboration and engagement

Some argue that online learning lacks the face-to-face interaction of traditional classrooms, but e-learning platforms have evolved to foster virtual collaboration and interactive experiences. E-learning facilitates collaboration and engagement among students [34]. Techniques and tools to increase student engagement, such as discussion forums, video conferencing tools, and collaborative project spaces, enable students to connect, communicate, and collaborate with their peers, irrespective of physical distance. This collaborative learning approach enhances student engagement and active participation, as students can share ideas, engage in meaningful discussions, and learn from diverse perspectives [35]. Furthermore, e-learning platforms often incorporate gamification elements and interactive multimedia, making the learning experience more engaging and interactive. E-learning has transformed education by providing equitable access, flexibility, personalized learning, and collaborative engagement [36]. As technology advances and e-learning platforms evolve, the potential for innovation and enhanced learning experiences will only grow. This shift towards e-learning represents a significant milestone in the evolution of education, bringing about new possibilities and opportunities for students and educators alike. By embracing and harnessing the power of e-learning, the educational landscape can adapt to the changing needs of learners, preparing them for success in a digital and interconnected world [37].

3. Harnessing the power of technology

Harnessing the power of technology is a crucial aspect of accelerated education and enhancing learning experiences [38], most especially in the post-pandemic era [39]. Technology integration provides opportunities for innovation, engagement, and personalized learning, transforming the way education is delivered and experienced [38, 39]. The following key technological tools play a significant role in this transformation:

3.1 Learning management systems (LMS)

LMS platforms serve as centralized hubs for educational content delivery, assessment, and communication. They enable teachers to organize and distribute course materials, assignments, and resources in a digital format. LMS platforms facilitate seamless interaction between teachers and students, allowing for efficient communication, collaboration, and feedback. Features such as discussion forums, chat functions, and online assignment submission streamline the learning process and provide a convenient space for student-teacher interaction [40].

3.2 Virtual reality (VR) and augmented reality (AR)

Immersive technologies such as VR and AR provide experiential learning opportunities that enhance understanding and engagement. VR creates

simulated environments that allow students to explore and interact with virtual objects, places, or scenarios. AR overlays digital information onto the real world, augmenting the physical environment with interactive digital elements. These technologies enable students to visualize complex concepts, engage in interactive simulations, and experience learning in a highly immersive and interactive manner. For example, VR can transport students to historical sites, scientific laboratories, or virtual field trips, enhancing their understanding and engagement with the subject matter [41].

3.3 Gamification and game-based learning

Gamification involves incorporating game elements and mechanics into educational activities to enhance motivation, engagement, and learning outcomes. By introducing elements such as points, levels, leaderboards, and rewards, educators can make the learning process more enjoyable and interactive. Game-based learning takes gamification a step further by integrating educational content into actual games. This approach allows students to learn through play, promoting active participation, problem-solving, and critical thinking. Gamification and game-based learning tap into students' natural inclination for competition and challenge, fostering a sense of achievement and accomplishment as they progress through educational tasks and activities [42].

3.4 Data analytics and adaptive learning

Technology enables the collection and analysis of vast amounts of data, which can inform data-driven decision-making in education. Data analytics tools provide insights into student performance, engagement, and learning patterns, allowing educators to track progress, identify learning gaps, and make informed instructional decisions. Adaptive learning systems leverage data analytics to personalize instruction based on individual student needs. By analyzing student data in real-time, adaptive learning platforms can dynamically adjust content, pace, and difficulty levels to match each student's unique abilities and learning preferences. This personalized approach enhances student engagement, optimizes learning outcomes, and ensures that each student receives targeted support and guidance [43].

In summary, harnessing the power of technology through the integration of Learning Management Systems (LMS), Virtual Reality (VR), Augmented Reality (AR), Gamification, and Data Analytics can revolutionize education by providing innovative and engaging learning experiences. By leveraging these tools effectively, educators can create dynamic and personalized learning environments that cater to the diverse needs of students, foster critical thinking and problem-solving skills, and prepare them for success in the digital age. The integration of technology into education is a key factor in shaping the future of learning and empowering students to thrive in an ever-evolving world.

4. Redesigning learning spaces

Redesigning learning spaces is crucial to support blended and online learning, creating environments that foster creativity, flexibility, adaptability, and active engagement [44]. The following aspects should be considered when redesigning

physical learning spaces. We will discuss fostering creativity in education, flexibility, active learning environments and outdoor and community-based learning.

4.1 Fostering creativity in education

This is of utmost importance in preparing students for success in the modern world. It plays a vital role in developing critical thinking, problem-solving, and innovation skills that are essential for navigating complex challenges. To prioritize creativity and imagination, learning spaces need to be redesigned to create an environment that encourages exploration, experimentation, and risk-taking. By granting students the freedom to pursue their interests and make choices, educators can effectively nurture their curiosity and foster a sense of ownership over their learning journey [45]. Collaborative problem-solving tasks are key in promoting creativity. Through group work, students are exposed to diverse perspectives and ideas, which stimulates their innovative thinking. Redesigned learning spaces should be purposefully designed to facilitate collaboration and group activities, providing the necessary resources and arrangements that encourage effective teamwork. This collaborative approach empowers students to engage in brainstorming, discussions, and collective problem-solving, fostering a creative mindset that enables them to find imaginative solutions to real-world challenges. Integrating interdisciplinary approaches into the curriculum further enhances creativity in education. Breaking down the traditional barriers between subjects encourages students to recognize connections and relationships between different areas of knowledge. This holistic approach to learning allows students to approach problems from multiple angles and develop a more comprehensive understanding. Redesigned learning spaces should support interdisciplinary learning by providing the necessary resources, materials, and collaborative spaces that facilitate the integration of various subjects [44].

In order to foster creativity, educators should incorporate open-ended projects that allow students to explore their own interests and ideas. These projects encourage students to think critically, solve problems, and innovate. By embracing ambiguity and encouraging students to take risks, educators create an environment that nurtures creative thinking. Redesigned learning spaces should provide the tools, materials, and spaces needed to support these open-ended projects, allowing students to freely express their creativity and develop their problem-solving skills [45].

4.2 Flexibility and adaptability

Learning spaces need to be adaptable to support various learning modalities and seamlessly accommodate transitions between in-person and online instruction. Flexible furniture arrangements, technology integration, and multimedia displays enable teachers and students to switch between individual work, group collaboration, and virtual learning seamlessly. This adaptability allows for a blended learning approach, where traditional face-to-face instruction is combined with online resources and interactive technologies, offering a more personalized and dynamic learning experience [46].

4.3 Active learning environments

Redesigned classrooms should embrace student-centered approaches that promote active learning. Flexible seating options, interactive displays, and makerspaces can

facilitate hands-on learning experiences and provide opportunities for exploration and creativity. Educators can incorporate project-based learning, design thinking, and arts integration across the curriculum to foster creativity and critical thinking. These approaches empower students to take ownership of their learning, fostering curiosity, collaboration, and a growth mindset [47].

4.4 Outdoor and community-based learning

Connecting education with the real world is essential for holistic development. Outdoor learning spaces and community engagement provide opportunities for experiential learning, promoting a deeper understanding of concepts and fostering a sense of civic responsibility. Utilizing outdoor spaces, such as gardens, nature trails, or local community resources, allows students to explore and apply their knowledge in authentic contexts. Community partnerships, field trips, and service-learning projects provide avenues for students to connect with the local community, broaden their perspectives, and develop essential life skills [48].

By redesigning learning spaces to prioritize creativity, flexibility, adaptability, and active engagement, educators can create environments that foster student agency, curiosity, and a love for learning. These redesigned spaces promote collaborative problem-solving, critical thinking, and innovation, preparing students for the challenges of the future. It is important to recognize that the physical learning environment plays a significant role in shaping the learning experience and supporting the integration of e-learning, creativity, and technology in education.

5. Empowering educators

Educators play a vital role in the successful implementation of e-learning, creativity, and technology. Here are the three key aspects to consider:

5.1 Professional development

Continuous professional development programs are essential to equip teachers with the skills and knowledge needed to effectively integrate technology and creative approaches into their teaching practices. Training workshops, seminars, and online courses can provide educators with opportunities to enhance their digital literacy, learn about innovative teaching strategies, and explore creative methodologies. By investing in ongoing professional development, teachers can stay abreast of the latest advancements in educational technology, understand how to leverage digital tools effectively, and adapt their instructional practices to meet the needs of diverse learners [49].

5.2 Shift in roles

As education evolves in the post-pandemic era, the role of teachers is transforming. Rather than being the sole source of knowledge, teachers become facilitators, guides, and mentors, supporting students' learning journeys. They create engaging learning environments that foster critical thinking and nurture creativity. Instead of delivering lectures, teachers encourage student exploration, collaborative problem-solving, and self-directed learning. By embracing a student-centered approach, educators

empower students to take ownership of their learning, make connections between different subjects, and develop essential skills for the future [50].

5.3 Collaborative learning communities

Collaboration among educators is crucial for fostering innovation and growth in the classroom. Creating collaborative learning communities within schools or across different institutions can provide teachers with opportunities to share best practices, exchange ideas, and support one another. This collaborative approach enables educators to tap into a collective pool of knowledge, learn from each other's experiences, and adapt innovative strategies to their own teaching contexts. Through professional learning networks, online communities, and collaborative projects, teachers can stay connected, receive feedback, and continuously refine their instructional practices [51].

Empowering educators is fundamental to the successful implementation of e-learning, creativity, and technology in education. Continuous professional development programs enable teachers to acquire the necessary skills to integrate technology effectively and foster creativity in their classrooms. The shift in roles from traditional teaching to facilitation and mentorship positions educators as guides in students' learning journeys. Additionally, fostering collaborative learning communities provides a platform for educators to share best practices, collaborate, and inspire innovation. By empowering educators, we create a supportive and dynamic environment that enhances student learning and prepares them for the challenges and opportunities of the future.

6. Rethinking assessment practices

Assessment methods should align with the evolving nature of education, focusing on holistic and authentic evaluation. These are the three aspects of consideration:

6.1 Competency-based assessment

Moving away from traditional standardized testing, competency-based assessments focus on evaluating students' skills, application, and real-world problem-solving abilities. This shift emphasizes the mastery of specific competencies and allows students to demonstrate their understanding through practical applications. Competency-based assessments provide a more comprehensive and authentic measure of students' abilities, as they assess not only knowledge acquisition but also the practical application of that knowledge [52].

6.2 Portfolios and multimedia presentations

Allowing students to showcase their learning through portfolios, multimedia projects, and reflective journals encourages creativity, critical thinking, and self-assessment. Portfolios provide a collection of students' work samples that demonstrate their progress, growth, and achievements over time. By incorporating multimedia elements such as videos, presentations, and interactive content, students can demonstrate their understanding in engaging and dynamic ways. This form of assessment encourages students to think creatively, reflect on their learning journey, and develop metacognitive skills [53].

6.3 Continuous feedback

Technology plays a crucial role in facilitating timely and personalized feedback, enabling formative assessment, and promoting student growth and reflection. Online platforms, learning management systems, and digital tools provide opportunities for teachers to provide feedback in a timely manner, allowing students to make adjustments and improvements. The use of automated feedback systems, adaptive learning platforms, and peer assessment also enhances the feedback process. Continuous feedback helps students understand their strengths and areas for improvement, fosters a growth mindset, and encourages self-reflection [54].

By rethinking assessment practices, educators can move towards a more holistic and authentic evaluation of students' learning. Competency-based assessments prioritize the development of practical skills, while portfolios and multimedia presentations allow students to demonstrate their creativity and critical thinking. Continuous feedback, facilitated by technology, supports student growth and reflection. These assessment approaches not only provide a more comprehensive understanding of students' abilities but also promote self-assessment, metacognition, and lifelong learning skills. By aligning assessment with the evolving nature of education, we ensure that students are prepared for success in a rapidly changing world.

7. Promoting equity and inclusion

In the post-pandemic era, reimagining education requires a strong emphasis on promoting equity and inclusion [55]. This involves addressing disparities in access to technology and resources, creating inclusive learning environments that value diversity, providing targeted support to marginalized students, and challenging biased practices [56]. By prioritizing equity and inclusion, we can build a more just and inclusive educational system that ensures equal opportunities for all learners [57]. Here are three key strategies to prioritize equity and inclusivity:

7.1 Ensuring access

To bridge the digital divide, policies and initiatives should focus on providing equitable access to technology and internet connectivity for all students, regardless of their socioeconomic status or geographical location. This includes implementing infrastructure improvements, establishing community partnerships, and offering affordable or subsidized internet and device options. By addressing the access barriers, we can ensure that all students have equal opportunities to engage in e-learning and benefit from technology-enabled education [56].

7.2 Universal design for learning (UDL)

Implementing Universal Design for Learning principles involves adapting instructional materials, assessments, and technologies to meet the diverse needs of learners. UDL recognizes that students have different learning styles, abilities, and preferences. By offering multiple means of representation, engagement, and expression, educators can create inclusive learning environments that reduce barriers to learning. This may involve providing captioning or transcripts for multimedia

content, offering flexible options for demonstrating knowledge, and incorporating assistive technologies to support students with disabilities [20].

7.3 Culturally responsive pedagogy

Technology and e-learning platforms should embrace diverse perspectives, cultural representation, and authentic content to create an inclusive and empowering learning environment. Culturally responsive pedagogy recognizes and values students' cultural backgrounds, experiences, and identities. It involves incorporating culturally relevant materials, incorporating inclusive language and imagery, and providing opportunities for students to share their unique perspectives and experiences. By creating a culturally affirming and inclusive learning environment, educators foster a sense of belonging and empower students to actively participate and contribute [58].

By prioritizing equity and inclusion, reimagined education can address systemic barriers and create a more accessible and inclusive learning experience for all students. Ensuring access to technology and internet connectivity, implementing Universal Design for Learning principles, and embracing culturally responsive pedagogy are key steps in creating a learning environment that values and supports the diverse needs of students. Through these strategies, we can promote equity, foster inclusivity, and provide every student with an equal opportunity to thrive and succeed in their educational journey.

8. Ethical considerations and digital citizenship

The integration of technology necessitates ethical considerations and the development of digital citizenship. Below are the 3 areas to consider:

8.1 Responsible technology use

Educating students on digital literacy, privacy, security, and ethical online behavior is essential in fostering responsible technology use. Students need to understand the importance of protecting their personal information, respecting copyright and intellectual property rights, and behaving ethically in online spaces. By providing guidance and resources on digital citizenship, educators can empower students to navigate the digital world responsibly and safely [59].

8.2 Media literacy

In the age of abundant information and digital media, it is essential to equip students with critical thinking skills to evaluate and analyze digital content. Media literacy enables students to discern reliable sources of information from misinformation, propaganda, and fake news. By teaching students how to evaluate the credibility, bias, and accuracy of online sources, educators empower them to make informed decisions and engage in responsible digital discourse [60].

8.3 Digital well-being

As technology becomes more pervasive in education, it is crucial to promote a healthy balance between screen time and physical activities. Educators should

emphasize the importance of maintaining digital well-being by encouraging students to practice mindfulness, take breaks from screens, engage in physical exercise, and foster healthy relationships both online and offline. By nurturing digital well-being, educators support students in developing a healthy relationship with technology and maintaining their overall well-being [61].

Integrating ethical considerations and fostering digital citizenship in education ensures that students become responsible and ethical users of technology. By educating students on responsible technology use, promoting media literacy, and nurturing digital well-being, educators empower students to navigate the digital landscape confidently and ethically. These skills are essential for students to become active and responsible participants in the digital world, contributing positively to society and upholding ethical values in their online interactions.

9. Collaboration and global connections

In the rapidly evolving landscape of education, technology plays a pivotal role in fostering collaboration and global connections among students. Here are three key points to consider:

9.1 Virtual exchanges

Technology allows students to engage in collaborative projects and virtual exchanges with peers from around the world. Through these interactions, students can develop intercultural understanding, empathy, and appreciation for diverse perspectives. Virtual exchanges provide a platform for cultural exchange, language practice, and collaborative problem-solving. By connecting students globally, technology breaks down geographical barriers and expands students' horizons, preparing them to be global citizens in an interconnected world [62].

9.2 Interdisciplinary learning

Technology facilitates cross-disciplinary collaboration, enabling students to explore real-world problems from diverse perspectives. Through online platforms and tools, students can collaborate with peers from different disciplines to analyze complex issues, propose innovative solutions, and gain a holistic understanding of various subjects. Interdisciplinary learning encourages students to think critically, synthesize information, and apply knowledge from multiple domains. By leveraging technology, educators can create opportunities for students to work collaboratively across disciplines, fostering creativity, critical thinking, and problem-solving skills [63].

9.3 Global resource sharing

Online platforms provide access to a vast array of educational resources, allowing educators and students to tap into a global pool of knowledge and expertise. Teachers can share teaching materials, lesson plans, and best practices with colleagues worldwide, fostering professional development and the exchange of innovative ideas. Students can access digital libraries, online databases, and educational websites that offer diverse perspectives and information. Global resource sharing through technology enhances the quality of education by exposing students to a wide range of

perspectives, cultures, and ideas, promoting a deeper understanding of global issues and encouraging students to become informed global citizens [64].

By harnessing the collaborative and connective power of technology, educators can cultivate collaboration and global connections in the classroom. Virtual exchanges, interdisciplinary learning, and global resource sharing provide opportunities for students to engage with peers from different backgrounds, explore interdisciplinary topics, and access a wealth of educational resources. These experiences enhance intercultural understanding, promote critical thinking, and foster global citizenship. Through technology-enabled collaboration and global connections, students are empowered to become active participants in an interconnected world and make meaningful contributions to their local and global communities.

10. A LEAP forward in mathematics Education inspired during COVID

With the foundations of e-Learning, redesigning learning spaces and harnessing the power of technology, we studied other online learning systems and we endeavored to build a personalized learning system that would support PreK-12 education flexibly and adaptively; mapped to our state's educational standards and national standards in mathematics. Our project is LEAP (Learning Explorations Accelerated Program). COVID-19 necessitated a shift to online education, posing challenges for PreK-12 students worldwide. We reflected on children at home and parents trying to assist or teachers assisting them through Zoom. Virtual Instruction was particularly challenging for many students, and we aimed to improve learning opportunities and outcomes for PreK-12 students. The latest National Assessment Educational Progress (NAEP) results show that on average, nationwide math and reading scores for thirteen-year-olds are the lowest in decades. We will discuss the design of our web-based mathematics education system designed to support students in exploring mathematical concepts and skills. The system offers grade-specific courses and allows customization based on individual learning needs. As the student progresses through the math content, the system will determine if they have acquired the prerequisite knowledge for understanding that grade-level course. At the end of completing a content area for a grade, there is a personalized proficiency test which boosts students up or down depending on the outcome of the test. There are 10 questions from the different areas of that content area for a total of 100 points:

- if the student scores 80% or higher, they accelerate to the next level which can be within the current grade level or higher grade in the mapping scheme.
- If the student scores 50–79%, they are given extra lessons to remediate on the topics of interest and given the proficiency test again. This rule is repeated if necessary.
- If the student scores 49% and lower, the system will use the pre-set PreK-12 mapping scheme and navigate to lower grade(s) of that sub-content area to ensure that they have the prerequisite knowledge, take quizzes for that grade and pass, before they return to their current grade-level. Once they are complete, the test is administered again. This rule is repeated if necessary.

We want it to be very accessible and to support teachers in uploading new lessons and assignments like a Learning Management System but enhanced through foundational materials developed and based on state and national standards. In this proof of concept, we are focusing on mathematics reinforcement and acceleration activities. The framework for this system is aimed as a template supporting adaptation to other concept areas. We plan this system to monitor student progress and provide parents and teachers with acknowledgment of their progress. This project aims to contribute to the advancement of online learning, accelerated learning, and user design and user experience in online learning systems.

The model comprised several vital components, such as curriculum design and customization. We plan to provide grade-specific mathematics curricula aligned with state educational standards. We will support flexibility for teachers to add customized curricula based on their students' needs, supporting many learning styles and abilities. We have planned interactive and personalized Learning Resources with various interactive resources such as videos, virtual interactive activities, and games. These resources facilitate active engagement and conceptual understanding, providing practice and acceleration opportunities to strengthen mathematical skills.

We have also designed student assessments through formative and summative assessment tools to evaluate students' understanding and progress. Teachers should have access to real-time data and analytics to monitor individual and class performance, identify areas of improvement, and provide timely feedback.

10.1 Design and development considerations

When designing and developing the mathematics education website, several considerations were considered User Interface Design through an intuitive, visually appealing, and easy to navigate application. Clear and concise instructions, well-organized content, and consistent design elements contribute to a positive user experience. We also considered Web Usability and we prioritized web usability principles to ensure accessibility and ease of use for all users, including those with disabilities. Compatibility with different devices and browsers, efficient loading times, and responsive design are crucial factors to consider.

We began with a set of functional requirements supporting our conceptual model as follows:

- This system can support teachers to view and check students' homework, exam, quiz, and give Feedback.
- This system can allow teachers to create new online lessons, quiz, exam, homework, and upload syllabus.
- This system can support teacher to check students' task completions, and learning progress.
- This online learning system supports students to complete and submit their assignments online.
- This online learning system supports anytime and anywhere access by students for acceleration or reinforcement activities.

We then completed empathy maps to empathize with our users, persona to have better understanding of user requirements, low-fidelity wireframes to create layouts of the system and then developed the front-end website. We also planned and are developing the back-end Infrastructure, which is necessary to increase the robustness of the website. This back-end will also assist in handling website traffic, user data, and interactive features with efficient data storage, security measures, and regular backups as essential considerations for effective system.

Evaluation and Analysis We have performed preliminary analysis and are planning more rigorous use of the application once we have completed the system and preliminary testing with current and pre-service teachers. We will utilize both qualitative and quantitative measures for our analysis. The analysis will include quantitative measures, such as pre-questionnaires, post-questionnaires and performance metrics, as well as qualitative measures, such as interviews and focus groups. Our summative evaluation will focus on students' learning outcomes, engagement, user satisfaction, and the website's impact on teaching practices.

11. Conclusion

This work shares our view on the state of education as seen through the lens of a post-COVID pandemic landscape with many hurdles that have been made much more apparent. This post-pandemic era marks a pivotal moment for education, where we can reimagine and reshape the entire educational landscape. By leveraging the power of e-learning, creativity, and technology, we can revolutionize educational delivery methods, experienced, and valued. We have discussed some of our high-level design of a designed and developed system LEAP that we plan to help students through this crisis.

This holistic approach to education emphasizes the creation of inclusive and student-centered learning environments. It recognizes that each student has unique needs, interests, and learning styles, and strives to provide tailored educational experiences that foster their individual growth and development. Through e-learning platforms, students can access educational resources and engage in interactive learning activities that transcend the limitations of traditional classrooms. This enables students from diverse backgrounds, regardless of their geographical location or socioeconomic status, to have equal access to quality education.

Furthermore, by integrating creativity into the educational process, we empower students to become active participants and creators of knowledge. Creativity nurtures critical thinking, problem-solving, and innovation—the skills necessary for success in an ever-changing world. By incorporating project-based learning, design thinking, and arts integration, we provide students with opportunities to explore their own ideas, collaborate with their peers, and develop the creativity and confidence to tackle real-world challenges.

Technology serves as a powerful tool in this transformation of education. By embracing e-learning platforms, learning management systems, virtual reality, gamification, and data analytics, we can enhance the learning experience and cater to individual student needs. Technology facilitates personalized learning, adaptive instruction, and data-driven decision-making, ensuring that students receive the support and guidance they require to excel academically and develop a deep understanding of the subjects they are studying.

In this reimagined education system, educators play a central role as facilitators, guides, and mentors. They create a supportive and stimulating environment where

students can explore their interests, develop their talents, and cultivate their passions. Empowering educators through continuous professional development programs equips them with the necessary skills and knowledge to effectively integrate e-learning, creativity, and technology into their teaching practices. Collaboration among educators, as well as the establishment of professional learning communities, fosters a culture of innovation and sharing of best practices.

This transformative approach to education not only prepares students academically but also equips them with the skills and qualities needed to thrive in the digital age. By nurturing creativity, critical thinking, collaboration, and global citizenship, we empower students to become lifelong learners who can adapt to and contribute positively to a rapidly changing world.

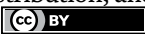
Ultimately, the reimagining of education in the post-pandemic era is an opportunity to break free from the constraints of traditional educational models. By embracing e-learning, creativity, and technology, we can create an education system that is more responsive, inclusive, and engaging. Through this holistic approach, we can empower every learner to reach their full potential, ensuring that they are well-prepared to navigate the challenges and opportunities of the digital age and contribute meaningfully to society.

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Preparing Students with Twenty First Century Skills for the Future Post-Pandemic Era

Dina Shouman, Amani Itani and Anwar Kawtharani

Abstract

Educational policy makers, employers and other stakeholders are urging schools and universities to promote twenty first century skills, such as teamwork, problem-solving, and self-management, which are regarded as important for success in the workplace, citizenship, and family life. These skills are critical for success in the modern world because they allow people to negotiate complex situations, form strong connections, and achieve their goals. Furthermore, these skills are not set characteristics, but rather may be acquired and enhanced via conscious practice and feedback. This chapter will focus on the importance of integrating twenty first century competencies into education to bridge gaps between education and the workplace in the post-pandemic era. The COVID-19 pandemic has highlighted the need for digital transformation since students are expected to possess different twenty first century competencies such as digital literacy, problem-solving, adaptability, and communication skills. This chapter will explore how educators can prepare students with these skills through authentic learning experiences like project-based learning (PBL) and internships. It will also examine the challenges of transitioning from academia into the workplace, and how businesses and educational institutions need to collaborate to ensure that students are equipped with the skills needed for success in the modern workforce.

Keywords: twenty first century skills, competencies, post-pandemic era, workplace, employability skills

1. Introduction

In recent years, there has been a rising understanding of the value of twenty first-century skills and competences such as creativity and innovation, digital literacy, and social and civic responsibility for success in the workplace, citizenship, and family life. Educational policymakers, companies, and other stakeholders are asking schools and universities to incorporate these competences into their curricula in order to better prepare students for modern-day difficulties [1]. The COVID-19 pandemic has underlined the necessity of digital transformation and providing students with the skills they need to flourish in an ever-changing and increasingly digital society [2]. As a result, this chapter will investigate the significance of incorporating twenty first-century competences into education in order to bridge the gap between school and the

workplace in the post-pandemic period. This chapter encourages educators to provide authentic learning experiences like project-based learning (PBL) and internships to prepare their students for critical skills including digital literacy, problem-solving, flexibility, and communication. It will also look at the obstacles of transferring from academia to the workplace and how businesses and educational institutions can work together to ensure that students are prepared for success in the modern workforce. Overall, this chapter provides a thorough grasp of the significance of twenty first century skills and competences in education, as well as the efforts educators and institutions may take to prepare students for success in a post-pandemic environment.

2. Research review

2.1 Digital transformation and literacy in education

The COVID-19 pandemic has brought to light the importance of digital transformation and literacy in education. According to research, the pandemic has hastened the implementation of online learning and digital technology in education, as well as exposing the digital divide that exists between students and teachers [3]. Research has shown that digital literacy is necessary for success in the twenty-first century industry, and pupils with higher levels of digital literacy are more likely to thrive academically. The Covid-19 pandemic revealed that children who lack digital literacy abilities face barriers to obtaining school and fully participating in the digital economy [4]. According to research, digital transformation in education is about more than simply technology; it is also about pedagogy and curriculum design. Curriculum designers must consider the changing requirements of the digital age, and digital literacy and other twenty first century competencies must be incorporated into learning objectives and evaluation criteria. Additionally, teachers must be trained on how to properly use digital tools and create interesting online learning experiences that promote collaboration and critical thinking. The transformation of education relies on the actions and beliefs of teacher teachers, as they are the main deciding stakeholders regarding students' learning experiences and if any changes in the curricula are to be implemented [5].

Additionally, unlike never before, students live in highly connected and interactive environments as they utilize their phones, tablets, laptops and other devices to access the virtual world of messaging, social media platforms. And, as students enter the classrooms today leaving the virtual world behind, the delivery of instruction is catching up and shifting towards integrating information and communication technologies (ICTs) and focusing on digital literacy in the classroom, especially when students are able to submit assignments and access class materials online when they are home [5]. ICTs via the Internet have paved the way for new learning contexts, pedagogies, and learning outcomes. Thus, providing teachers with the needed resources for technology integration, teachers' technology competence, and teachers' perceptions of technology play a major role in how they integrate technology tools in the classroom for developing students' twenty first century skills [6].

The impacts of teaching students twenty first century skills have encouraged the spread of inclusive STEM high schools (ISHSs), which are schools that serve all students regardless of prior academic achievement. With student centered learning being the main priority, ISHSs foster the development of students' twenty first-century skills, including adaptability, effective communication, problem-solving, critical

thinking, collaboration, and self-regulation [7]. Such programs are impactful because they provide students opportunities for knowledge construction, real-world problem solving, skilled communication, collaboration, use of ICT for learning, and self-regulation in teacher lesson plans and student work samples [7]. These skills foster the long-term academic achievement and career pursuits of students.

3. Acquiring twenty first century skills through authentic learning experiences

By offering students authentic learning experiences, they are encouraged to tackle problems that lack a definitive answer. This type of learning requires them to think critically and creatively, employing unique methods and techniques to find innovative solutions [8]. When students are active participants in meaningful student-centered learning environments, they are more likely to come up with new ideas, share those ideas, enhance each other's cognitive processes, and evaluate their own and their peers' academic ideas [9].

Internships are an integral part of authentic learning experiences and they place students at the center of learning. Internships emphasize the development of life-long learners with positive and constructive experiences in today's work environment [10]. As academic institutions develop internship programs, they focus on significant advancements, transformations, and progressions related to education and instruction [11]. Research has shown that after the Covid-19 pandemic and the dissemination of internships as part of students' learning experiences, students appreciated an internship-study balance through distance learning [11]. Internships, whether in-person or online, are anticipated to enhance the employability of graduates, since they provide valuable support in smoothly transitioning from the academic to the professional world [12]. One skill that students learn is skill-based learning, which is when students learn to apply theoretical knowledge in real-world practical scenarios. Online internships or e-internships present students with opportunities such as cultivating proficient virtual communication skills and effectively convey ideas, concepts, and work materials within a computer-mediated setting. This entails that students possess the technical competence to complete such e-internships. E-internships also provide students with cognitive learning outcomes, since they require students to have intrinsic motivation to take a lead in asking questions, performing tasks, voicing out their thoughts and seeking advice [12]. This could be viewed as a challenge that accompanies e-internships, since the students' mentor is not supervising their day-to-day activities and challenges as closely as in an in-person internship setting.

Another form of authentic learning is PBL, also known as real-world problem solving. In such tasks, students are expected to actively discover real-world problems, develop solutions targeted to a specific project, test their suggested solutions, and successfully communicate and share their ideas with others. Such experiences encourage student creativity and personal development, as students' achievements and setbacks are not evaluated based on a fixed set of criteria as seen in traditional classroom environments. Teachers also benefit from PBL, as the skill of collaborative learning allows teachers and students to engage in a shared process of exploration and learning [13]. Collaborative learning has the potential to cultivate constructive interactions and facilitate learning activities such as inquiry, explanation, justification of opinions, articulation, argumentation, and expansion of ideas. As such, students

learn the construct of knowledge sharing where they generate individual ideas, share ideas with their peers and develop shared understanding [14].

PBL also fosters twenty first century capabilities like critical thinking, problem-solving, interpersonal communication, information and media literacy, cooperation, leadership and teamwork, innovation, and creativity [15]. Research that has compared the results of two groups of students who were exposed to online PBL vs traditional lectures showed that those exposed to online PBL had statistically significant better computing skills in month 36 than students exposed to traditional lectures [16]. PBL fits into activities built into an internship, as they both align in structure and outcomes such as including the processes of student readiness, problem analysis, problem-solving, and evaluation [17]. By engaging in internship opportunities and PBL projects students engage in real-life projects that enhance their critical thinking and problem-solving abilities as they address open-ended problems that closely resemble the types of challenges they will encounter in professional environments [18].

4. Transferring twenty first century skills from academia into the workforce

Measuring students' abilities to perform twenty first century skills prepares them for the expectations and professional standards of the industry [19]. It is essential to equip students to attain employability skills they will use once they graduate to effectively work in a professional setting. The unexpected advent of the Covid-19 pandemic in early 2020 nearly immobilized the world of global education. Since then, the education system has made some strides to reform its learning strategies in order to establish more robust learning models that meet the needs and demands of industries. During the COVID-19 pandemic, students were unable to participate in real-world internships and work placements. As a result, virtual internships and job experience have been used to facilitate learning experiences. Because of the limited time given to students, instructors were forced to consider alternatives. Virtual internships did not previously match the minimum qualifications, however due to the ongoing COVID-19 situation, instructors were forced to reconsider. Virtual worlds are ideal for students who are required to participate in authentic learning experiences. Additionally, situational role playing can still be observed in online situations. For instance, job owners, managers, work personnel have built online exercises that allow students to observe how things work. Virtual workspaces are being designed and customized to meet specific learning objectives and needs [11]. Because of the reduced time and travel costs, these opportunities contained more extensive experiences than would be possible in real life. Following the COVID-19 pandemic, the use of virtual workplaces is projected to continue due to its ease of use and risk minimization [20].

A twenty first century skill that students acquire from participating in authentic learning experiences is the utilization of ICT for learning. As students are in the process of knowledge sharing, generating new ideas and testing them out, they also learn what ICT tools choose and how to use them, and are able to identify reliable online sources of information [7]. One framework teachers are encouraged to explore is the TPACK framework, which encourages ICT-integrated lesson design [21]. This framework encompasses the application of educational theories, lesson preparation, adaptation to various learning styles, and student assessment in the context of utilizing technology for learning. TPACK is implemented when teachers employ their technological knowledge, pedagogical knowledge, and content knowledge to

develop targeted strategies for integrating ICT into instruction. A crucial aspect regarding digital literacy is that there is a digital divide between schools that have technological opportunities and those with limited resources and poor infrastructure [22]. This highlights the importance of working towards providing equal access to ICT tools regardless of students' socioeconomic backgrounds [23]. Furthermore, it is essential to ensure that teachers receive adequate training opportunities to possess the necessary technological skills to effectively guide students towards adopting technology with a positive mindset [24]. Technology-enhanced learning opportunities can develop students' twenty first century competencies, such as thinking and problem solving, interpersonal and self-directional skills, and digital literacy [25]. For instance, lessons that include ICT incorporate real-world challenges, current and authentic informational resources, virtual tours of remote locations, concept simulations, or engagement with experts and global communities [25]. Thus, when students engage in meaningful, relevant, and intellectually stimulating tasks, their performance in the classroom improves, since the curriculum content becomes more personally significant to them, making it easier to comprehend and master.

Additionally, teachers are encouraged to be knowledgeable about the Fourth Industrial Revolution (4IR), such as artificial intelligence (AI), Internet of things, robotics and virtual reality. Such terms are changing the economic, social, and political structures worldwide [26]. Thus, the 4IR is another reason why teachers should alter how they teach twenty first century skills, which in turn emphasizes the role of the TPACK framework in preparing teachers to effectively teach students. Since teachers are considered significant in the field of education, they need to gain a full understanding of how to effectively use emerging tools like AI tools to successfully integrate this technology into the classroom and to support their students. This increases the need for teachers to receive support in terms of curriculum planning, resources, training, and pedagogical approaches to ensure the successful implementation of technology-based teaching in schools. Teacher preparation to deliver twenty first century skills is highlighted because their self-efficacy beliefs can influence and anticipate their achievements and improve students' learning outcomes [27]. Perceptions of self-efficacy influence people's choices, motivations and behavior. Thus, teachers' skills and knowledge in using technology are influencing factors in how they deliver instruction in online learning [28].

Authentic learning experiences shape students' identities, as immersing them in knowledge and practice of digital literacy offers them twenty first century skills like guided, purposeful, and critical examination of their own discourse [29]. Digital literacies present an advantage to include students' voices and identities in the lesson, since unlike blackboards and overhead projectors that require students to focus on the teacher and the board, personal computers and online spaces motivate and facilitate curiosity, communication, and cooperation [30]. For instance, Curwood and Cowell, developed a digital poetry curriculum for high school sophomores called iPoetry to incorporate digital literacy practices that "enhance students' critical engagement, increase their awareness of audience, and encourage their progressive use of multiple modalities" (p. 111). When teachers are creating the curriculum, they should keep in mind "what is to be learned and how it is to be learned" [30]. Because students are familiar with using technology in their daily lives, this way of learning allows teachers and students to create communities of inquiry where students and teachers use a range of ICT tools to co-construct knowledge [31]. For example, in a music class where students were asked to use music software packages to express their styles of music, the teacher mentioned that this exploratory project that was an integral part

of students' social and cultural lives was an opportunity for her to learn more from the students, rather than them gaining the instruction from her [31]. Teachers are also encouraged to use multimodal approaches that include ICT like using movies, TED Talks, digital texts, memes, and social media posts. Classroom activities like this include diagnostic assessment, students' identities, and the use of ICTs. When ICT is accompanied by individualized learning, then the classroom will be transformed into a learning community that embraces students' cultures while studying the curriculum using ICT. For instance, students in an English class were asked to produce media texts by creating websites, and they were able to create dynamic projects that expressed their thoughts and unique voices by incorporating ideas being presented by their teachers and their out-of-school experiences [31]. Teachers and students work within a classroom culture that is influenced by in-school and out-of-school factors. This means teachers should use methods to include students' unique knowledge and experiences into the classroom. There is evidence that suggests that how students use technology in the classroom is affected by out-of-school cultures of use [31]. Drawing on socio-cultural theory, when students use technology in the classroom, they form knowledge based on what they have previously known and believed.

Recommendations are made to improve e-internships, which have the potential to be authentic workplaces in the post-COVID era. However, there are certain factors to be considered when dealing with having effective e-internships such as faculty mentors' preparedness, industry mentors' preparedness, interns' readiness toward online internship, and interns' Internet efficacy [32]. Schools are encouraged to develop equitable programs that address their students' pedagogical, technological and social needs. When implementing authentic learning experiences as part of students' learning, it is recommended that both students and educators receive technical training to enable them to effectively navigate the difficulties associated with using ICTs, digital literacy, remote learning and e-internships. It is also essential to update software programs to offer educators and students with more updated features and is less prone to errors caused by software glitches commonly known as bugs [11]. An academic-industry collaboration is pertinent to design authentic learning experiences that prepare students to meet the needs of their employers. In such collaborations, students partake in internships and PBL experiences, where they learn the competencies that employers require prior to employment [33]. Additionally, when teachers become part of professional learning communities such as partaking in professional development opportunities, they pave the path for collectively constructing knowledge and undergoing the needed pedagogical changes. This is where the role of the TPACK framework in education is emphasized since it puts together the knowledge required by teachers to design lessons that include ICTs, especially considering the rapid advancements in technology [34]. To ensure valuable learning experiences for students, educators must possess the necessary training and skills for designing effective learning environments, implementing appropriate assessment methods, and offering essential student support.

5. Conclusion

The COVID-19 pandemic has highlighted the need for digital transformation in education, and that students must possess various twenty first-century competencies like digital literacy in order to excel in the digital age. This can be done by providing students with authentic learning experiences like internships and PBL. A major

attribute for authentic learning is that it provides immersive learning experiences that offer students the chance to actively participate in real-life situations. Students can better understand the value and practicality of what they learn in the classroom by relating it to situations and problems in the real world. Including ICT in curriculums affects how students access information, communicate, and learn within and outside of classrooms. As students engage in authentic learning experiences, they learn twenty first century skills like critical thinking, adaptability, creativity, digital literacy, the use of ICTs, cooperation and cultural competence, which improves their knowledge and sparks their enthusiasm for learning. Through internships and PBL, students develop into lifelong learners who are prepared to successfully navigate the ever-changing digital world. With the rapid emergence of new technologies, there is a constant need to make changes in what twenty first century skills students acquire and the methods through which they learn them. Further, the TPACK framework transforms how learning in the classroom takes place, as it focuses on what teachers need to know to incorporate technology in the classroom. How teachers integrate technology is a crucial facet, and developing unified theoretical and conceptual frameworks solidifies the proper intersection between content, pedagogy and technology. Educational institutions, policymakers, and educators must realize the impact that authentic learning experiences have on students' learning outcomes, and this begins by giving teachers the necessary assistance, materials, and professional development to develop and implement such curriculums into educational systems. The inclusion of technology in the classroom goes beyond students' lives inside of the classroom, as it ties into narrowing the achievement gap by preparing learners for future opportunities and necessary skills they will need to become competitive in a global, knowledge-based economy.

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Higher Education in Mongolia: Before and After Pandemic

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Abstract

Mongolia is the second largest landlocked country in the world. The development of a country depends a lot on educated mass of the nation. Therefore, the education system, especially the higher education system of Mongolia is facing many challenges today. In the early 90s, the education system was managed by Russian influence and after the 90s the situation changed dramatically. Many private universities were established after democratic movement in the country. During the pandemic period, Mongolian education sector faced many problems, same as with other countries. But Mongolian Government managed education during the pandemic successfully and is now looking forward to focus on the quality of higher education. This chapter will cover the state of the education system in Mongolia, especially after pandemic period.

Keywords: Mongolian education system, higher education in Mongolia, post-pandemic education, online teaching, online learning

1. Introduction to Mongolia

Mongolia is located in the middle of the Asian continent. Mongolia has 1,564,116 km² area and counts as the 18th biggest country in the world [1] with a population of 3.409 million [2]. Moreover, Mongolia is the second largest landlocked country [3] after Kazakhstan in the world (**Figure 1**).

Mongolia has 71.1 million livestock, an inflation rate of 12.2%, GDP of 52.9 trillion and 4.8%, unemployment rate of 5.3%, average household income of 1.8 million, and labor force participation of 57.9% respectively [5].

Table 1 shows that Mongolia is one of the youngest nations in the world. Children up to 14 years old in total 1,095,258 which is 32.12% of the whole population. Young people between ages 15 and 24 are in total 454,602, which is 13.33% of the population. Active working population between ages 25 and 59 is 1,597,695 which is 46.85% of the population.

One of the highlights of the country is its history. It is a nation which established and led one of the biggest empires in the world history. Mongolians have their own writing from that great empire. Writing development of the Mongolians is divided into several classifications: first period—starting from unknown year to the end



Figure 1.
Map of Mongolia [4].

Age group	Population
0–4	375,503
5–9	396,080
10–14	323,675
15–19	220,796
20–24	233,806
25–29	251,605
30–34	310,652
35–39	270,782
40–44	232,177
45–49	208,273
50–54	174,130
55–59	150,076
60–64	110,538
65–69	65,804
70+	86,042
Total	3,409,939

Table 1.
Age group of Mongolian population.

of the thirteenth century, second period—from the beginning of the fourteenth to end of the sixteenth century, third period—from the seventeenth century [6]. Later some other scholars updated these classifications: first period: before classical time century from the thirteenth to fourteenth, early years of classical time century from the fourteenth to fifteenth, late years of classical time century from the fifteenth to sixteenth, second period: classical time from seventeenth to twentieth century, third

Literacy Rate by Country 2023

[📄 CSV](#) [📄 JSON](#)

Country	Latest Rate ▼	Rate Year	2023 Population
Bulgaria	98.59%	2015	8,807,711
Mongolia	98.37%	2015	3,447,157
Marshall Islands	98.27%	2015	41,996
Spain	98.11%	2015	47,519,628
Argentina	98.09%	2015	45,773,884
Jordan	98.01%	2015	11,337,052
Serbia	98%	2015	7,149,077
Austria	98%	2011	8,958,960

Figure 2.
Ranking literate countries [10].

period: modern time twentieth century [7]. Since 1943, Mongolians accepted to usage of Cyrillic letters as basic writing [8]. Based on this change government increased literacy of population and as result of this action in 1946 already 95% of whole population was able to read and write with Cyrillic letters [9]. Nowadays, Mongolia (98.37%) [10] is one of literate country in the world (**Figure 2**).

2. Education system of Mongolia

Mongolian education system is divided into several parts: preschool education, elementary schools, secondary schools, postsecondary education, technical and vocational education, tertiary education, and lifelong education (**Figure 3**). All citizens of Mongolia have to enroll in schools starting from age 6, and it is confirmed by national law [11]. This law manages all policies for formal and informal education processes in the country.

Pre-school education law defines different types of the educational organizations [12]. The umbrella term for all those organizations is defined as “kindergarten.” The kindergartens are divided into several types depending on the targeted groups:

- Kindergarten—children from 2 years up to 5 years
- Special kindergarten—children from 2 years up to 5 years with special needs
- Sanatorium kindergarten—children from 2 years up to 5 years who need mental or body care
- Groups with extended hours—groups organized by request of parents, based on decree of kindergartens' director which works 1–3 hours longer each day
- Groups with shortened hours—groups organized by request of parents, based on decree of kindergartens' director which works 1–3 hours shorter each day

Age	Education institutions	Classes
0	Home (Pre-school education)	
1		
2		
3	Kindergarden (Pre-school education)	
4		
5		
6	Primary education	1
7		2
8		3
9		4
10	Lower secondary education	5
11		6
12		7
13		8
14		9
15	Secondary education	10
16		11
17		12
18	Postsecondary/Higher education technical and vocational education and training	1st sem
19		2nd sem
20		3rd sem
21		4th sem
22		5th sem
23		6th sem
24 and up	Lifelong education	

Figure 3.
Education system of Mongolia.

- 24 hours group—groups organized by request of parents, based on decree of kindergartens’ director and the local stakeholders who work all 5 working days for 24 hours

Main aim of this law is to provide all children the possibility to enroll into corresponding kindergarten before school. In the academic year 2022–2023 for preschool education 266,024 children enrolled, and corresponding 9450 primary teachers, 8277 assistant teachers worked with them [13].

By the law of “Elementary and primary education,” for primary education pupils need to study 5 years, for low secondary education 9 years, and for secondary education 12 years [14]. In 2023, 859 schools are working for 12 years of education in the country. 293 of them are located in the capital city Ulaanbaatar [15]. 746,400 pupils are studying in these schools.

In the academic year 2022–2023, 69 universities are actively working for higher education of the country. 47.8% of them count as universities, 50.7% as higher

	University	Cost for basic courses/Tugriks/	Cost for professional courses/Tugriks/	Total/ Tugriks/
1	Mongolian National University	98,600	100,700–120,800	2,900,000
2	Mongolian National University of Education	78,000	92,000	2,300,000
3	Mongolian University of Science and Technology	—	107,040	3,211,200
4	University of Finance and Economics	—	185,000	5,900,000
5	Mongolian National University of Medical Sciences	40,700	117,610	2,800,000
6	Mongolian University of Life Sciences	100,000	127,000–156,000	4,300,000

Table 2.
Tuition fee of universities (2022–2023) [19].

institutions, and 1.4% as colleges [16]. There are 16 public universities, 50 of them are private, and 3 of them are religious universities. For the most part, 92.8% of all higher institutions are located in the capital city Ulaanbaatar. The total number of students is 145,267, and there are 38.9% male and 61.1% female students. The number of employees in the higher education is 11,923 and 43.4% of this or 5169 are teaching staff.

Mongolian education was completely free of charge for all levels before 1990s. After democratic movement, education system of the country changed dramatically. There were many different changes in higher education and one of the new issues was fee for higher education. Tuition fee in 1994 was between 21,000 and 32,000 tugriks [17]. By opinion of some authors [18] higher education system of Mongolia needs to react to modern requests of labor market in sense of quality.

Tuition fees of universities usually change every year depending on the economic capacity of the country. Since 1992 universities converted to credit system as in the USA and other developed countries. Each year universities re-define their cost for a credit. **Table 2** shows the estimated cost of credits in some universities.

In 2022, Ministry of Education and Science, Statistics focused their attention to the quality of the universities. The minister of the Ministry of Education and Science, L.Enkh-Amgalan decided to cancel licenses of 13 universities which did not fit the requirements of the Ministry of Education and Science relating to quality [20]. To provide opportunities for continues study of enrolled students Ministry of Education and Science accepted to transfer 1500 students of those 13 universities to other universities.

3. Higher education in Mongolia: Before pandemic

The democratic change in Mongolia in 90s gave various choices for selection of universities for students. The new political movement affected dramatically in change of higher education of the country, simultaneously. Before democratic change in government all universities in the country were only of public status and all financial

issues were tasks of the government. All educations were free of any tuition fee including tertiary educations and professional educations.

The higher education system was established with the support of Soviet Union after World War II. It was almost a direct copy of Russian education system into Mongolia. But after 90s it changed fast and dynamically, which attracted interest of many national and international scholars [21–25]. After the change public universities started to change their status and names, moreover, many private universities with various programs were established [26].

The Asian Development Bank (ADB) supports in years the development of strategic issues of Mongolian education system. Projects with funding of ADB started getting implemented in different areas of education systems, such as Education Sector Development Program (ESDP) funded by ADB and in 1996 [27]. Not only ADB but many other international foundations and organizations invested in projects in education of Mongolia. In 2006, already 49 different projects were funded by international organizations as part of education [28].

e-Learning and distance learning started being implemented in higher education of the country actively after the implementation of Web 2.0 technologies with rapid development of internet. But e-learning was not welcomed by all faculty members of universities and even by students. Some study from 2019 showed that e-learning is effective only for master programs [29].

Professors at universities started to accept social media and tried to apply them as useful tool for teaching and learning. A study shows that social science professors are more adaptive to social media as a tool than natural science professors [30].

One of the biggest issues in development of higher education system was the financial issues. Before 90s, all education systems were public organizations and finance problems were solved by the government. After 90s, even public universities had to manage their own finances. Not only private universities, the so-called public universities such as: Mongolian National University (MNU), Mongolian University of Science and Technology (MUST) were almost confronted to manage their finance issues based on the students' study tuition fee [31].

With change of the structure and type of universities there were discussions on program development and revision of curriculums. Scholars studied on these issues and started to give recommendations to university stakeholders to do revision and fundamental change on curriculums [32].

Some scholars found out with their study that globalization is essential in higher education, and universities have to be aware of this point in their strategic plans and curriculum updates [33].

Higher education is the main focus of Mongolian families. Most parents, independently from their annual income, want to send their children to university. It is provided by various choices of private universities who cannot pass usual level for public universities. Due to this attitude of families in general, Mongolians are highly educated compared with other developing countries. Some study highlighted that an overeducation is happening in Mongolia and it can affect the labor market negatively [34].

By international scholars', a study discovered that Mongolian higher education reform in curriculum runs with the support and influence of European countries, and fund organizations from abroad [35]. The study program and curriculum updates are run under consultation from European countries and it can result in more western style of teaching in universities. Number of universities in Mongolia can make problems for higher education noted by international scholars [36]. Due to this issue,

Type of universities		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Universities	Total	113	101	99	100	101	100	95	96	94	95
	Public	16	15	15	16	16	17	17	18	18	21
	Private	97	86	84	84	85	83	78	78	76	74

Table 3.
Universities in Mongolia (2010–2019).

they concluded that the quality assurance should be handled with great care. Based on some internal and external assessment with focus on quality issues, it was recognized that information and communication literacy and computer skills need to develop as support for faculty members. Moreover, salary level of all kind of teachers’ needs to be increased to support quality in the education system of the country [37].

Table 3 shows statistic data [38] of higher education institutions (universities) between 2010 and 2019.

The statistics shows that in 2010 in total 113 higher education institutions are active in Mongolia. 97 of them were private universities, only 16 of them were public universities. Due to strategic policies of the Ministry, the number of universities were reduced in 2019. In 2019, 95 universities were active in the country. Number of public universities increased up to 21, and number of private universities decreased down to 74. Most universities were located in the capital city Ulaanbaatar. 85 universities are located in the capital city, and the remaining 10 are located in rural areas of the country.

Number of students in 2010 was 170, 100 and it decreased in 2019 with total number of 148, 400 [39]. International students’ number in 2010 was 1520 but it declined in 2019 to 959 (**Figure 4**). The reason for reduction of foreign students can be due to beginning of COVID-19 regulations worldwide.

Most wanted study direction in 2010 was Business and management, same as in 2019. But interest in study direction law increased from 8261 to 11,248 (**Table 4**).

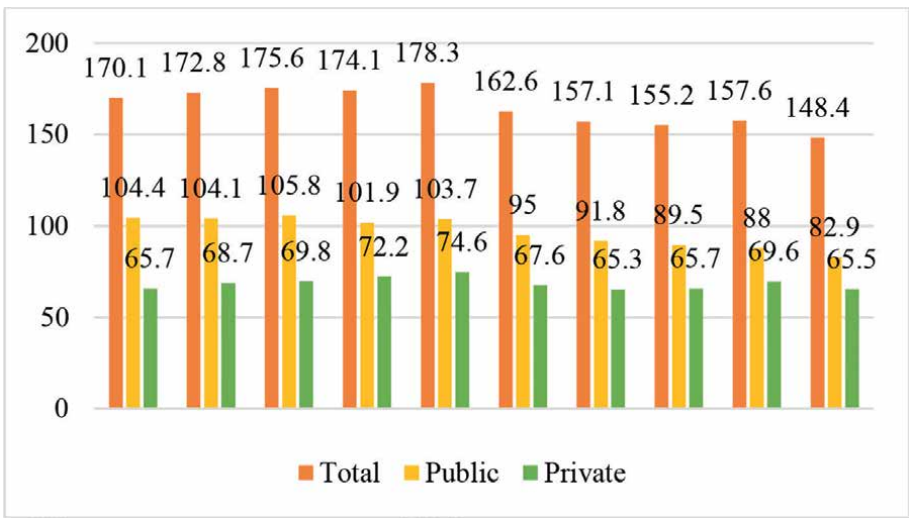


Figure 4.
Number of students (2010–2019).

Professional	2010	2019
Total number of students	170,126	148,446
Pedagogy	22,471	22,854
Humanity	11,610	7148
Art and Design	3147	4761
Law	8261	11,248
Social Science	11,864	5983
Business management	36,375	32,615
Mathematics and Computer Science	6722	5626
Service	8843	6528
Nature science	5210	3817
Medical science	17,995	20,903
Engineering	24,274	14,282
Architecture	5710	5596
Agriculture	4902	2239
Others	593	3300

Table 4.
Comparison of study directions (2010 and 2019).

Faculty members	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total	7183	7295	7331	7385	7528	7121	6917	6724	6668	7330
Female	4174	4287	4371	4542	4628	4368	4130	3997	4028	4491
Male	3009	3008	2960	2843	2900	2753	2787	2727	2640	2839

Table 5.
Faculty members (2010–2019).

Unfortunately, students in engineering were dramatically reduced from 24,274 to 14,282 [40].

Table 5 shows [41, 42] statistics about faculty members between 2010 and 2019. The **Figure 4** shows number of students between 2010 and 2019. And this fact demonstrated that number of students have been reduced from 2010 to 2019. But **Table 5** confirms that number of faculty members have not changed significantly during this period.

4. Higher education in Mongolia: During pandemic

The COVID-19 shocked education systems of almost all countries in the world. Mongolia could not avoid it as well. The neighboring country China was core of the pandemic and Mongolia had to manage accordingly to upcoming situations. Comparing with reaction of some other countries to pandemic and solutions for challenges by Mongolia were fast enough and correct [43]. Mongolian Government

established special committee at the State Emergency Committee (SEC) [44] and created the Disaster Protection Law to manage situations during pandemic [45–49].

One of main challenge of the education during COVID was engagement and motivation of students, who suddenly had to study from distance. Consortium of Mongolian Universities made decree to teach all courses fully online since 27th of January 2020 for all higher institutions [50] (**Figure 5**). Most universities used, as basic tools for online teaching, open course learning management systems like Moodle, Google Meet, Google Classroom and some commercial versions like Zoom and Skype.

To figure out the engagement rate as well as satisfaction level of students with the online teaching, scholars did various studies [51–55]. Most of studies showed that unexpected change of teaching and learning mode was a difficult situation not only for professors and teachers, but for students and learners as well. To estimate satisfaction of students regarding the quality of teaching during pandemic period, data from students at the end of second semester of academic year 2019–2022 were collected. In total, 202 students responded to this survey and 88% of them evaluated online teaching as satisfactory. This study showed that teaching hours and preparation needed for teaching increased by 1.2–2 times in comparison with normal teaching period [50] (**Figure 6**).

During COVID period world organizations supported education sectors of countries to unexpected situations with professional guidance. For example, Educational, Scientific and Cultural Organization of the United Nations provided different actual reports and experiences from countries in education sector [57].

There were various discussions related to higher education during pandemic. The critical situation required urgent and smart decisions which could react to actual problems of the pandemic. That period emphasized value of higher education and science. Universities tried to keep education processes active even it during unexpected situations. Some authors estimated that lack of higher education due to the pandemic will come out later and can be influence to world economy negatively [58].

The National Accreditation Committee together with About Asia Pacific Quality Network (APQN) organized an international conference on “Quality assurance of learning and teaching during pandemic” from 25th to 26th of November in 2020 [59]. Several experts from different countries were invited as keynote speakers to the



Figure 5.
Learning during pandemic online at home.



Figure 6.
Teaching during pandemic [56].

conference and highlighted about motivation of students during pandemic, support technical issues of students for distance learning, cooperation between students and lecturers on online teaching and learning. One of the conclusions from this conference was to focus on increasing the support for technical problems in teaching during pandemic period.

Digital competences of university faculty members, readiness of teaching skills of the staff was highlighted during pandemic. By the decree of the Minister of Ministry of Education and Science A/67 following points were highlighted in the education sector [60]:

- Policies of information and communication technologies;
- Curriculums and its evaluation;
- Teaching methodologies;
- Information and communication technologies;
- Learning management;
- Teachers' development

Regional UNISEF and UNESCO conducted a study on current situation on education during pandemic period for East Asia focusing on China, Japan, Republic of Korea and Mongolia. Comparison with other countries showed Mongolia reacted strongly to COVID-19 and closed duration time of schools was much longer than other 3 countries. As highlighted in the report "In Mongolia, schools were closed for an initial period of eight months, opened in September 2020 and closed again in November and are not due to reopen until March 2021." [61]. In this report the total budget impact of the focused countries was included. Collected data showed additional budgets which were needed to respond for COVID-19 from countries. The value of the budget ranges from \$677 million in Mongolia to \$315.8 billion in China in the baseline scenario.

5. Higher education in Mongolia

The strange period was over. However, the state of the education did not return back to daily life immediately. Strong long lockdown, sudden change in teaching and learning mode influenced to psychology of teachers and learners.

The education during pandemic brought teaching and learning to a new atmosphere. E-learning, online learning and distance learning were not so welcomed by learners and parents before COVID. But requested situation during pandemic period, teachers and learners had no choice, therefore, had to adapt to new teaching and learning environment: online and distance forms. This had positive impacts on education after pandemic. Distance and online teaching mode open new opportunities especially for higher education system. Mixed version of teaching and learning is more accepted by professors and students [62].

Sudden change of the teaching and learning mode was difficult challenge not only for students, it was a demanding change for professors all around the world. In 2020, universities performed self-evaluation for acceptance and adaptation of university lecturers and professors with new teaching modes: e-learning and distance learning [63]. Study results showed that professors faced problems with assessment of online learning and openly highlighted problems of change in teaching mode.

Scholars studied implementation of e-learning in higher education after the pandemic. The survey which collected data from 726 faculty members of various universities showed that 72.65% of the responses highlighted a need of corresponding teaching and learning environment for e-learning [64].

6. Conclusion

After the pandemic, for academic year 2021–2022, in total 148,954 students studied in 88 universities [65]. 79.5% of those universities had national accreditations. 89 study programs of 17 universities received international accreditation certificates. Number of international students were 1547 and most of them 76.4% were students from China (Figure 7).

Number of faculty members were reduced to 14.6% in 2022 comparison with 2021. Teaching mode has changed from traditional classroom teaching into online teaching during these years and this was one of the main reasons for this kind of reduction.

Nowadays biggest challenges which higher education is facing are digital literacy difference of analog professors and digital learners, different views on digital world of professors and students. Most professors of higher education institutions are aged over 40, born before internet, smart devices and social networks era [66]. Daily digital life was not known for today's professors for their student period or education years.

Next issue of modern higher education is hard and soft skills which students are expected to have during university years. Knowledge and proof of formal education were the most required measurements for the labor market in twentieth century. But situation dramatically changed with digital world and in twenty-first century hard and soft skills are more essential for any kind of labor markets. Mongolian Government recognized this issue and included special phase into "A Knowledge-based Society and a Skillful Mongol" objective as one of key target of the project [67].

An additional key point of higher education is the learning attitude of modern students which changed a lot due to the actual digital contents and huge opportunities of e-world.

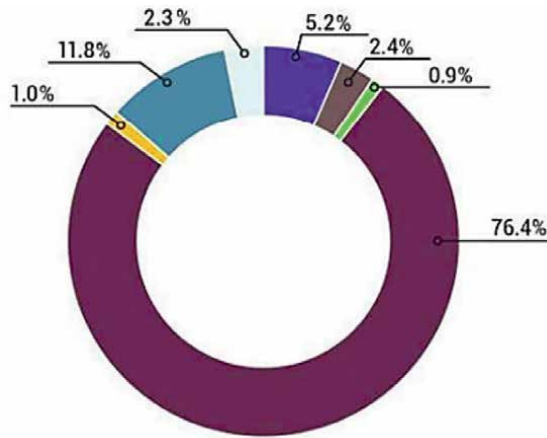


Figure 7.
International students in Mongolia [65].

Universities in Mongolia have tuition fees which is for some families not easy to pay. Therefore, the Government of Mongolia supports young people who received the right to study but are not able to pay the study fee. Since 1993 Mongolian Government started to distribute scholarship from “Government Foundation.”

Satisfaction of students with their study and learning environment is one of the key issues and scholars working on this. SERVQUAL, TIMKO and KANO models were applied to process data from university students in 2022. Result shows that many factors are important for satisfaction of students. Learning environments like: clean and comfortable classrooms, internet access and speed, employer communication skills, reputation of the university, and time managements, to name a few [68]. This study results were proofed by national scholars’ evaluation of influence factors for satisfaction [69].

Mongolian government is currently trying to estimate further development of higher education and conducted a study regarding the plans from 2020 to 2050 (Figure 8).

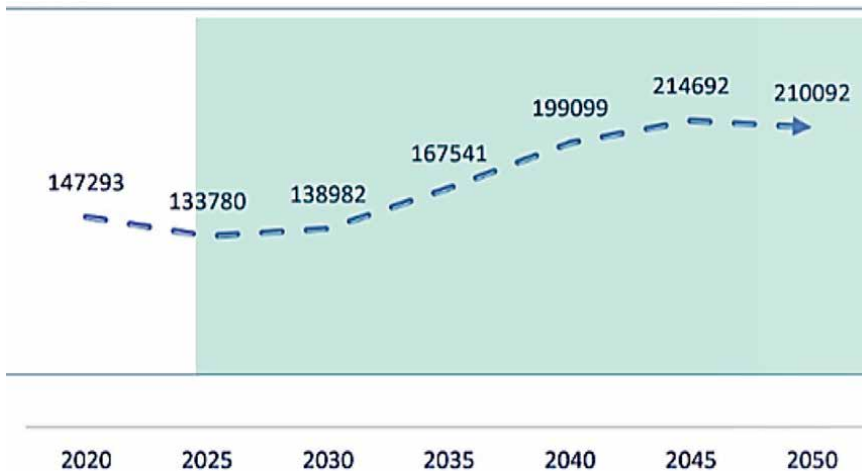


Figure 8.
Enrollment of students into higher education [70].

By this study, number of students will increase in coming two decades. Average age of students is between 20 and 34 by statistics and population in these ages will increase: total population between 20 and 34 will be 693,500 in 2025 and 1100 00 in 2050.

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Education stakeholders are at a crossroads where teaching and learning paths intersect with technologies fueled by emerging artificial intelligence. Educators who observe the residual effects of a global pandemic are left to wonder what creative technology solutions that sustain teaching and learning amidst mutating contagions should be retained, abandoned, or re-imagined to create sustainable pedagogy practices. In this book about e-learning, invited authors analyze the impacts of overarching issues facing educators across the globe to rethink how they deliver content and assess students' learning. A global community of scholars and researchers contributed twenty chapters to examine artificial intelligence, alternative assessments, education policy, creative technology, creative lesson plans, and emerging workforce trends to foster emerging paradigms in the post-pandemic era.

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