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Bosede Iyiade Edwards
Nurbiha A. Shukor
Adrian David Cheok *Editors*

Emerging Technologies for Next Generation Learning Spaces

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Adrian David Cheok
Editors

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Editors
Bosede Iyiade Edwards
Raffles University
Johor Bahru, Johor, Malaysia

Adrian David Cheok
i-University
Tokyo, Japan

Nurbiha A. Shukor
Department of Educational Science,
Mathematics & Creative Multimedia
Universiti Teknologi Malaysia
Skudai, Johor, Malaysia

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Chapter 1
Emerging Learning Technologies in Next Generation Learning Spaces: Implications for Learning and Cognition

Bosede I. Edwards, Nurbiha A. Shukor, and Adrian D. Cheok

Abstract Current growth and development points in the direction of classroom technologies beyond their previous roles as tools. This book presents discussions and studies on issues and possibilities in next generation education with a focus on the place of learning technologies within next-generation learning spaces. We aim to offer a holistic view of next generation learning technologies as all-encompassing, and in various educational roles as tools, as well as content, and environment. The central role of education in previous industrial revolutions and human society places a demand for education that counterparts the next change that will extend the status of current digitization to critical changes in the role of technology in human life. The chapters highlight perspectives on educational technology. Focusing mostly on developing and transition nations, they present pointers to the future, deriving from the experiences of educational technology instructors and researchers. Perspectives are from various backgrounds and classrooms, including mainstream classrooms and classrooms of special needs learners. Issues on how current global eLearning situation reflects on the Sustainable Development Goals (SDGs), especially to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" in line with SDG4 was also discussed. The issues addressed are intended to provoke further inquiry and studies within the field.

B. I. Edwards (✉)
Raffles University, Johor Bahru, Malaysia
e-mail: bosede@imagineeringinstitute.org

B. I. Edwards · A. D. Cheok
Imagineering Institute, Nusajaya, Malaysia

N. A. Shukor
Universiti Teknologi, Johor Bahru, Malaysia

A. D. Cheok
i-University, Tokyo, Japan

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1.1 Introduction

Several reports have focused on the extensive growth in the field of instructional technologies due to recent advancement in emerging media. It is also envisaged that the educational technology industry will be worth up to $331 billion by 2025 (Price, 2018). While this represents something good for education and development, there are also consequences and challenges that must not be overlooked. These changes will surely redefine the concept of literacy and illiteracy. Futurist Alvin Toffler is credited with the outstanding statement that inability to read and write will cease to be the definition of illiteracy in the twenty-first century; and illiteracy will be the inability to 'learn, unlearn and relearn' (Hennessy, 2002).

Within the context of formal education, this challenge must be addressed by not just learners, but also facilitators of instruction. This book discusses the place and role of emerging learning technologies in the evolving learning environments of twenty-first century education. It also addresses what implications they have for learning and cognition. We examined this topic based on factors including the most transformative technologies for the current classroom according to the Learning Technology Community (Price, 2018), critical transformations in education occasioned by both novel technologies and media, and the COVID-19 pandemic. A very vital foundation for issues discussed in the book also revolves around the idea of Sustainable Development Goal#4, that is, access to equitable quality education for all as proposed by the United Nations General Assembly.

The role that these technologies are playing in today's learning and how they are being used in various classrooms are examined in addition to the implications these changes have for education. Education is considered from both mainstream education, as well as in the education of learners with special education needs. Learning environments include physical, virtual as well as blended learning environments.

1.2 Emerging Learning Technologies

Technological developments continue to move at a very fast pace; so much so that it has become almost impossible to keep track of the emergence of new applications, tools, and media. Many of these technologies get lost in obscurity, with very few individuals, other than their creators, ever being aware of their existence. Some however become recognized in various fields where they quickly become solutions to real problems. Technologies that become well known, defined as 'science-based innovations with the potential to create a new industry or transform an existing one' (Srinivasan, 2008), are those recognized as emerging technologies. According to the business dictionary (WebFinance Inc., 2018), emerging technologies are 'new technologies that are currently developing or will be developed over the next five to ten years, and which will substantially alter the business and social environment'.

Application of emerging technologies may be general, or field-specific. They are usually recognized based on their effect, though some of the technologies have far-reaching effects across many fields. Abramovich (2018) described six (6) technologies believed to have the potential to transform human experiences. They include voice, facial recognition, Machine Learning (ML), Chatbots, biometrics and novel multimedia technologies like Virtual Reality (VR) and Augmented Reality. The top 10 emerging technologies of 2017 according to World Economic Forum and Scientific America (Perry, 2017) include quantum computing, sustainable communities, genomic vaccines, green vehicle technology, precision farming, the human cell atlas, artificial photosynthesis, and deep learning among others. Artificial Intelligence (AI), robotics, and Augmented Reality (AR) have also been identified across many fields as key emerging technologies believed to have important roles in the transformation of human life and society in the next industrial revolution.

Within the field of education, some of these technologies have been playing important roles and they are continually being applied to create innovative solutions in teaching and learning. The subject of emerging technologies in education is a current one in many studies, and their roles in next-generation learning spaces is being discussed. However, it is well-established that not only are they transforming the learning space, the concept of school, instructional design and delivery, but also, the learning process. They are essentially, altering the very foundations of education.

While the issue of emerging technologies in education is still being grappled with, at the end of 2019, the world was hit by a pandemic that almost turned humanity upside down. The whole of 2020, public places, including schools at all levels in most nations of the world were shut down, and the largest percentage of humans hid in the safety of their homes from the coronavirus. Education was forced to move into the internet space, thus becoming one hundred percent dependent on, enabled by, mediated through, and only possible through technology. It was season of technology-aided instruction like never before in the history of humanity. Video-conference classrooms on Zoom, Google Meet, Microsoft Teams, Webex and many more became the new schools. Teachers, parents, and learners were forced to adopt new ways of learning through these platforms while schools had to redesign instruction for delivery in these digital spaces. The 'future of education' thus came much faster than the world ever expected it to.

With this change came the emerging challenge of effective, fully online instruction. New teacher skills, learner skills, parental monitoring, and many more issues that were hitherto mostly optional became key concerns. While mainstream education is faced with these challenges in developed nations, developing economies were faced with additional issues including internet access, gadget affordability, power, and more. Outside the mainstream classrooms, the disability community faced more challenging issues that require different approaches. All of these issues together called into question the fulfilment of the United Nations (UN) Sustainable Development Goal (SDG) on education. Is technology actually going to be the magic wand to bridge the equity gap or enhance the already wide gap? Other emerging issues are physical, emotional and mental health issues in the use of these technologies and how they relate to effective instruction.

In the following chapters of this book, some of these issues are addressed by various instructors, researchers, and practitioners.

1.3 Next-Generation Learning Spaces

It is no more news that next-generation learning spaces will be much different from what obtains currently. The difference will also be much more drastic than what was observed between last generation learning spaces and those of current generation which has been made far more different than imagined possible within the decade due to COVID-19 pandemic.

Extensive debates have been on for some time on the nature of next-generation learning spaces, especially on the roles that technologies will play in its physical transformation and overall existence. Some questions that are still being debated include 'what types of classroom technologies can we expect to play critical roles and what roles will they play?'; 'how will this affect the concept of physical schools, physical classrooms, teachers' roles, critical classroom concepts like attendance, teacher-student interaction, assessment, instructional delivery, etc.?' Some of these questions are what the authors in the various chapters of this book set out to address. While authors do not intend to suggest there are absolute answers to the questions raised, especially as we expect even more drastic changes within the landscape in the near future, they provide views inspired by education research and practice in last and current generation learning, as basis for expectations for the future.

This first chapter provides and overview of the book and each of the chapters. The rest of the book include seven chapters addressing various topics regarding classroom technologies in next-generation learning spaces. Each chapter focuses on a different issue related to technology and its application in education. It is hoped that the issues raised, and concepts discussed will inspire projects, system developments, longitudinal studies, and further discussions in the community, and among research colleagues, towards promoting effective stakeholder engagements, especially for responsive teacher preparation and professional development for next-generation education.

Chapter 2, 'Emerging Trends in Education: Envisioning Future Learning Spaces and Classroom Interaction' focuses on the transformation in classroom interaction by emerging technologies and how this might impact teaching and learning. Based on an envisioned future learning space with a mix of physical/virtual humans and non-humans and machines as tools or participants, various forms of interactions including instructor-learner, learner-learner, learner-machine, instructor-machine (including robots) and other forms of interactions are envisaged. Critical issues raised include connectivity, safety and privacy concerns, ethics, as well as the implications for teaching, teachers' roles and teacher training and development, evaluation and assessment, instructional design, and overall learning and cognition. The implications of this imminent change for education and especially classroom technologies are highlighted. The important role of education in preparing the workforce for the industry is also discussed in addition to the implications for instructing the new generation of learners. The implications for education inspired recommendations for practitioners and other stakeholders.

In Chap. 3, 'Future of eSpecial Education: Options for Equitable eLearning Opportunities for Learners with Special Education Needs (SEN)', the authors discussed technology-enhanced learning (TEL) beyond mainstream classrooms. They highlighted the nature, challenges, limitations, and other issues related to online education within the disability community. The authors highlighted how education of SEN learners in these digital classrooms (eSpecial Education) fared during the pandemic. The implications, especially in relation to SDG4 was discussed, while options for addressing issues raised were also highlighted.

In the wake of the pandemic, as classrooms moved over to the digital space, one issue that remained unsolved was hands-on learning in physical laboratories in STEM learning. Most institutions simply postposed labs with the hope of a post-lockdown revisit. Therefore, in Chap. 4, the authors addressed 'The future of science labs; choosing a Virtual Laboratory for Hands-on Instruction in Physics Education'. Possibilities and options for virtual science labs were discussed. Though the authors focused on the physics laboratory in their discussion, their recommendations are applicable to instructing through science labs in other STEM fields.

In Chap. 5, the authors of 'ICT Masterplans in Education: Singapore's Reform Efforts to Engage in a Post-COVID World' provided a review of Singapore's National Information and Communication Technology (ICT) Masterplans from 1997 till date. Their submission provides descriptions of the implementations of the different plans and the valuable lessons that other national systems within the region and beyond can learn from. With nations more than ever needing to integrate ICT in their education systems, the review provides directions and suggestions that developing and transition nations can adopt, or adapt.

Following the discussion on ICT Masterplan, the author of Chap. 6 shares an insider view of instruction in online classrooms of the pandemic lockdown era in developing nations. The 'Status of Equitable Learning Opportunities in the Digital Space in the Pandemic Era: The Nigerian Experience' highlights the challenges faced in online learning in a developing nation. The chapter emphasized how technology access and use for learning during the pandemic lockdown enhanced the ever-widening gap between privileged learners and their underprivileged counterparts. It called to question the assumed potential of technology to bridge equity gaps, and solve the problem of equitable and quality access to education. The implications for graduate competitiveness and other relevant issues were also discussed.

Chapter 7, the last chapter, 'Reducing Cognitive Load in Emerging Digital Learning Environments through Peer Instruction' discussed the implications of extraneous processing for the memory system, especially within digital learning spaces. As more of learning moves online, the nature and direct implications of cognitive (over)load for human working memory, and how to mitigate this in online and technology-mediated instruction are discussed. In a mixed-mode study of university students in Malaysia, the author highlights important elements of pedagogy that teachers can leverage for promoting instruction in twenty-first century technology-aided, but distraction-loaded learning environments.

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Chapter 2
Emerging Trends in Education: Envisioning Future Learning Spaces and Classroom Interaction

Bosede I. Edwards

Abstract Learning environments have always been critical aspects of the teaching and learning landscape. They play key roles in both classroom interaction and overall learning experience, and have important implications for the use of classroom technologies. With critical changes in learning spaces occasioned by emerging technologies, important changes are expected in the nature of interaction and operations within learning spaces. This chapter discusses the roles and impacts of various types of emerging technologies and the emerging social interactions they foster in the classroom, as well as the implications for education. Focused technologies include robotics, artificial intelligence-powered systems, and virtual/augmented realities. The implications for teacher preparation and development for next-generation education are also highlighted.

Keywords Learning environments · Future learning spaces · Classroom interaction

2.1 Introduction

Learning have come a long way from the traditional, master-apprenticeship-style approach (Kaygin et al., 2020), through the industrial, theatre-style classroom with the teacher as the sage-on-the-stage (Mindshift, 2013), to its recent half-way-out-of-the-walls and teacher-as-facilitator and co-learner status. Other than learners and instructors, the learning environment (LE) is the other most important factor in education at all levels. Studies in education have attested to the significance of the LE for influencing student behavior (Guardino & Fullerton, 2010) and overall learning. Its critical role in student satisfaction and performance (Barrett et al., 2015; Yang et al., 2013), and overall effective instruction, including motivation, interest, and attendance (Park & Choi, 2014) have been discussed extensively.

B. I. Edwards (✉)
Raffles University, Johor Bahru, Malaysia
e-mail: dr@bosedeedwards.com

Imagineering Institute, Nusajaya, Malaysia

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Current learning environment come in online, offline, or blended modes. The characteristics, merits and demerits of each have also been reported extensively in many studies. A key aspect of learning environment is the 'classroom' atmosphere, generated by the overall effect of the interaction between the stakeholders and tools present within the space. These traditionally include instructors, learners and learning technologies. Developments in emerging technologies have continued to play significant roles in the transformation of current learning spaces and more learning continues to happen online. Learners are increasingly empowered to determine what, when, how and where to learn. Complete degree programmes as well as postgraduate programmes are now available online with recognized certification. Several tuition-free short courses also offer several opportunities for developing tailored skills which offer some advantages, including workplace relevance and significance compared with school-based instructions.

2.2 Envisioning Classroom Interaction in Future Learning Spaces

Learning spaces provide the environment for classroom interaction. Instructor-learner, instructor-technology, learner-learner, learner-technology are some of the interaction types observable in previous classrooms. With emerging technologies, other possibilities are emerging, fostering more complex classroom interaction. Instructor-learner-technology, learner-technology-learner and their variants are among the new kinds of interactions already being noted. Emerging media like Virtual and Augmented Reality (VR/AR), robotics, AI, and in the pandemic era, several video-conference classrooms, are becoming commonplace as classroom technologies or learning environments. As such, learner-content interaction is not only mediated by technology but situated within it. The promise of non-human instructors (Edwards & Cheok, 2018) as physically present or telepresence instructors (Tanaka et al., 2014) is also creating new interactions whereby, rather than being just media or tools within the environment, they are becoming actual stakeholders, and interaction with them is not only creating person-technology systems, but person-person systems with these technologies playing traditionally human roles.

It has been noted that the most important skills for next-generation education will be higher-order skills like logical or critical thinking and creativity (Al-Atabi, 2018); educators must therefore continually reinvent, and prepare themselves for the inevitable changes that advancement in technology is bound to bring. If that was not real enough, the outbreak of the Covid-19 pandemic across the world engendered an unexpected situation in education that inadvertently moved technology-enhanced learning many decades forward. With schools across the world forced to onboard their students and teachers to fully online classrooms in video-conference settings, the world was forced to fast-forward in decades. Education stakeholders everywhere are still grappling with the effects while hoping things will be back to 'normal' again. Whether they will or not is a different issue entirely.

As machine capabilities continue to expand, and demands in the workplace extends from manual to cognitive jobs, drastic changes in the education landscape are to be expected. Personalized or collaborative classrooms on VR, touch-enabled anatomical models, atomic or molecular models within Augmented Reality (AR), life-sized or miniaturized robots and various types of telepresence and humanoid robots in the classroom as teachers or peers can be expected. Hyper-connected classrooms, powered by Internet of Things (IoT), with all items able to communicate with each other and with the humans, are no more remote possibilities. With the amount of information currently available to the learner, and advances in distance education, the emergence of a new kind of learning, new kinds of learners and learning environments are no more sci-fi ideas and their full realization are definitely closer than imagined.

2.3 Progress in Robotics and Future Possibilities

Recent studies (Goel et al., 2020; Marzano & Martinovs, 2020) have confirmed that a combination emerging technologies will play major roles in the transformation of social interaction, including education. Several possibilities are being imagined. Machine learning will have tremendous impact on AI, which, together with advances in robotics will result in the emergence of new digital beings; intelligent robots with functional capabilities far beyond those of their predecessors. Twenty-first century robots have made tremendous progress and are far more capable than their predecessors. Today, robots appear as not only digital systems, but also as physically embodied and realistic humanoid systems, playing roles previously assumed to be possible for only humans.

Asimo robot, created by Honda can climb stairs, run at 9 km/h, recognize faces, and maintain a conversation. Nao (Ismail et al., 2012; Vanderelst & Winfield, 2018), a humanoid robot by Aldebaran/Softbank Robotics is a self-learning concierge robot, it dances and assists in dance training for kids. Many social robots are also playing several roles as front desk officers, medical attendants and support staff, or as home service or recovery therapy assistants in medicine and elderly care. The twenty-second Robocup International Competition and Symposium held in Montreal (Palais des congrès, 2018) played host to 35 countries, 5,000 robots, and 4,000 human participants. Sophia, a robot by Hanson (2019) is a 'naturalized' citizen of Saudi Arabia; there are several records of interviews she has granted (YouTube, n.d.). She discusses her 'dreams', and even expressed hopes to have 'children' of her own in the future! All these highlight outstanding progress already made and hints at future possibilities.

2.3.1 Educational Robotics and Future Learning Spaces

Robots have featured in various forms in teaching and learning and studies (Moerland et al., 2018; Oudeyer et al., 2016) have reported the effectiveness of robots in addressing several issues including motivation, engagement, and interest within teaching and learning. Improved attendance has also been reported in connection with robot-aided instruction. Tegos et al. (2014) acknowledged the usefulness of dialogue-based conversational agents for learning. They reported the value of agent's intervention in sustaining dialogue, and acceptance by students and teachers. Dennis et al. (2016) focused on Intelligent Tutoring Systems, suggesting the importance of adapting progress feedback and emotional support to learner personality. Robots in education have also featured as AI-powered systems. In their review of three decades progress in AI in Education (AIED), Roll and Wylie (2016) identified the shift in characteristics and priorities in education to include changes in goals, practices and environment as well as the role of the teacher. They noted an increased presence of AI in education settings and how this supports the development of interactive learning environments with their unique affordances compared with human tutors. These affordances are excellent resources for next generation education, especially for supporting anytime-and-anywhere learning (Fitter et al., 2018; Rosasco et al., 2020).

Robots as Pedagogical Agents (Johnson & Lester, 2016), elements of smart classroom systems (Timms, 2016) and online instructors have also been extensively reported especially in terms of the effectiveness of robotics courses for developing various skills among learners. Liu et al. (2013), for example, described how a robotics course promoted the development of assembling skills, idea sharing, problem solving and teacher-student interactions. Researchers and developers are however still on the debate of the role of independent robots in the classroom of the future, especially as it relates to their roles as teachers (Edwards & Cheok, 2018). However, more studies (Reich-Stiebert & Eyssel, 2016; Tutor, 2017) continue to point in the direction of a partnership with, rather than a replacement of, humans, as the future of educational robotics.

2.3.2 Potential of AI and Machine Learning in Future Learning Spaces

From medical services to drug design, and from military service to the regular classroom (Chen & Engkvist, 2019; He et al., 2019; Huang & Rust, 2018; Kessler, 2018), AI shows up everywhere and anywhere in the social landscape. Band (2018) believes AI has become 'our reality'. Based on current capabilities of AI for self-learning, which is enabled by machine learning, many Intelligent Tutoring Systems (ITSs) are emerging within education with capabilities for transforming offline or online instruction. Telepresence robots have the potential to cut the costs of education and professional teachers, for example, by providing access to native English speaker teachers in other parts of the world in language learning. Such robot systems are already helping in teaching and learning and assisting in addressing teacher-student language barriers (Tanaka et al., 2014). Telepresence robot teachers like EngKey are also currently being used as English teachers in Korea (Flatley, 2012). Such systems override international, geographical boundaries (Tanaka et al., 2013).

Robots as teaching assistants have also been reported in Japanese (Akashiba et al., 2017) and Korean schools (Fernández-Llamas et al., 2018). Their potential roles as independent teachers in future classrooms have also been discussed (Edwards & Cheok, 2018). Robots, AI personalities and various types of intelligent systems are potentially integral part of future education, where they will play different roles. These intelligent, robotic instructors can also be expected to feature in home settings as well; playing many roles including those related to learners with special needs. Robot lesson teachers and study partners may become affordable for, or programmable by, individual students and teachers for personal learning. Developments in natural language processing and understanding will further increase possibilities in future learning. Various roles within future 'school' systems are expected to be transformed by this developments, and such systems can only now be imagined.

2.3.3 Potential of New Media as Future Transparent Technologies

Emerging multimedia applications have focused on the integration of multisensory modalities for promoting learning. Reports on the development of virtual and augmented reality-based systems abounds in fields like medical education, aeronautic engineering, and others where simulation plays major roles in learning (Guého et al., 2021; Seo et al., 2018). Studies have also highlighted their ability to promote hands-on learning as well as engagement (Edwards et al., 2018; Flavián et al., 2019; Makransky & Lilleholt, 2018). Developments in VR/AR systems is progressing towards enhancing multisensory learning. Several virtual learning environments are also integrating immersion and leveraging simulations thereby lending reality to abstracts in ways that promote learning. Simulated chemistry laboratories like second-life (Bortnik et al., 2017; Su & Cheng, 2019; Winkelmann et al., 2017), virtual physics laboratories (Bogusevschi et al., 2020; Galan et al., 2017) and similar systems are becoming increasingly available and accessible. Several subjects can be taught using such tools, with additional opportunities to cut out both costs of materials as well as the dangers of explosive materials. In no distant future, they may become completely integrated into teaching and learning as transparent technologies.

2.4 Implications for Theory and Practice

2.4.1 Solving the Problems of Hands-on Learning Through Virtual Labs

Considering that one of the major challenges faced by science and engineering education/research during the pandemic is laboratory-based instruction, the future of multimedia technology will be captured in AI-powered systems that can afford explorations far beyond what is currently available. Collaborative learning within virtual spaces leveraging AR or VR systems, and enabling remote attendance at classrooms will completely remove the remains of geographical boundaries in education, and may completely change the concept of school or classroom attendance.

2.4.2 Presentation and Operation of Physical Schools and Classrooms

Will there still be physical schools in the future or will schools and classrooms be completely wall-less, ubiquitous, socially-connected, virtual spaces? Are there possibilities of blended schools or will traditional schooling persist through times into the future? These and many others questions have implications for teaching and learning. Current support for remote attendance in classrooms, especially the possibilities that have been seen and proven during the pandemic lockdown, as well as the affordances of telepresence will go a long way in supporting fully online learning. More virtual schools will emerge, and universities across the world are already offering online degrees at all levels of studies, including doctoral degrees.

2.4.3 Telepresence, Transactional Distance and Social Presence

Transactional distance (Moore, 2018; Stöhr et al., 2020; Weidlich & Bastiaens, 2018), that is, the disconnect in virtual learning spaces, has been linked to issues of social presence and identity (Lowenthal & Dennen, 2017). Its effect on effective understanding and communication among instructors and students has been a major discourse in distance learning. In envisioned future learning spaces, the challenge of transactional distance may become fully addressed by telepresence. It will also be able to support class attendance from home. It's potential to address issues of absenteeism due to illness has already been reported in studies like Melendez (2017) who showed how a post-surgical 11-year-old pupil in a Maryland elementary school attended classes from home through telepresence. She not only participated in class, but ‘strolled’ the halls with her best friend, and joined her classmates at the school cafeteria’. Emerging technologies definitely hold the promise of unimaginable opportunities.

2.4.4 Teaching, Teachers’ Roles, Teacher Training and Development

The capabilities of emerging technologies will definitely change instructional delivery. We can expect more of collaborative and peer tutoring, and robots as learning peers in both regular classrooms (Baxter et al., 2017; Walker & Ogan, 2016) as well as in the instruction of learners with special education needs (Bargagna et al., 2019; Rudovic et al., 2018; Zhang et al., 2019). The popularization of video-conference platforms during the pandemic lockdown has added a third model in which teachers and learners operate in fully online ‘classrooms’ that require no presence in, or operations from, any formal classroom. Possibilities with telepresence or robot teachers as well as teaching with emerging multimedia systems will create new or additional roles for instructors and classroom teachers. Improvements in currently available video-conference software can be expected to support more effective virtual instruction. The need for new instructional packages in line with emerging ‘subjects’, and delivery modes, and the management of classroom media systems may create demands for teacher-technicians with needs for programming skills. Teachers as technical operators or managers of new and complicated classroom technologies will also be in demand. This will in turn necessitate the review of teacher preparation and development programmes to capture these new roles.

2.4.5 Evaluation and Assessment

There is a revolution in educational assessment and some institutions have started to relax the rules as far as traditional assessment is concerned. Concerns on the place and nature of assessment in future education are however demanding closer looks. Questions are already being raised on the need for assessment in an era when information on all subjects, including teacher questions and answers are available online. If traditional assessment remains, how might it be mediated by technology? Options for remote testing and the use of proctoring software (Sando et al., 2021) are already being explored to address this, and though there are currently challenges with their effectiveness, and the fact that they have remained largely untried and tested on any large scale (Hussein et al., 2020), yet, future improvements are definite possibilities. For example, in their study of multiple assessment approaches, including proctored examinations, Morgan et al. (2021) confirmed the consistency of online video proctoring in exam structure and administration compared with other options.

In the absence of examinations, what will evaluation of learning look like? These, and other similar questions are among concerns regarding the future of education. It is becoming clear that as time progresses, the history of education may be doing the round, going back to the era of apprenticeship, when assessment was strictly based on practical demonstration of learning and skills. However, with all that there is to know freely available online, and not a preserve of instructors any more, the idea of apprenticeship may need to be redefined.

2.5 Conclusion and Suggestions for Future Studies

Though internet connectivity continues to improve, some emerging technological systems require very high broadband for proper functioning. It is not uncommon for users to experience disconnections or very poor connectivity or video and/or audio lags and other issues during lessons. Affordability of setup and operation costs for the required technologies is another huge challenge for learners and schools in poor communities. Safety, for example during very close interaction with machines by young learners, or safe handling of some of these systems, are also emerging issues. Privacy concerns may also arise, for example regarding telepresence school attendance where teachers or entire schools may be subject to monitoring by parents from home (Melendez, 2017). As stakeholders begin to ask questions about their rights in the new classrooms, the issues may necessitate the development of new policies, or review of old ones regarding ethic and codes of conduct for teachers, students, and schools. Ethical practices in terms of interactions between human learners and robot teachers, telepresence learners and teachers, etc. will also need to be addressed. This may extend to legal issues in relation to human-machine interactions. Other issues may include parental intrusions in telepresence classrooms, or inappropriate intrusion in learner-to-learner interactions by virtue of telepresence viewing privileges. Issues of 'zoom fatigue' is already coming up in learning discourses and may become critical in the future. Others are what changes might become necessary regarding holidays and leaves for staff in an era of 'work from home'?

Emerging technologies have always played significant roles in changing classroom practices, and formal education make changes to accommodate such developments. However, current changes have been adjudged the most drastic, with the potential to change human life and society in unimaginable ways. Longitudinal studies reporting impact on social, health and physical well-being of teachers and students are required to address various issues noted and others inherent in the system. In addition, differences in human societies need to be examined and findings leveraged in the development of culture-sensitive systems.

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Chapter 3
Future of eSpecial Education: Options for Equitable eLearning Opportunities for Learners with Special Education Needs

Nagora Banu Ohalezim, Bosede I. Edwards, and Toyin Janet Aderemi

Abstract This chapter discusses digital learning, particularly internet-based instruction, outside mainstream education. It highlights the nature, challenges, and limitations of online instruction in the education of persons with disabilities. The chapter discusses how education of Special Education Needs (SEN) learners in digital classrooms, tagged 'eSpecial Education' fared during the pandemic. Lessons learnt, and implications for the education SDG is discussed, and options for addressing issues raised were also highlighted.

Keywords Special education · eSpecial education · Special needs learners · SEN · Disability · Online learning · Equitable learning opportunities · SDG4 · Malaysia

3.1 Introduction

The 2030 Agenda for Sustainable Development (UNESCO, 2016; UNESCO Institute for Statistics, 2018) is a plan of action comprising 17 Sustainable Development Goals (SDGs) covering economic, social and environmental dimensions of human life and society. The SDG 4, or the education goal, focuses on inclusion, equity and quality with respect to educational opportunities. It aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all". The goal consists of 3 sub-SDGs, 4a, 4b and 4c and an additional 7 targets, making up the 10 key targets for the SDG. The focus of target 4a is to 'build and upgrade education facilities that are child, disability and gender sensitive and provide safe,

N. B. Ohalezim
Reading Pants SB, Johor Bahru, Malaysia

B. I. Edwards (✉)
Raffles University, Johor Bahru, Malaysia
e-mail: dr@bosedeedwards.com

Imagineering Institute, Nusajaya, Malaysia

T. J. Aderemi
Ayahulet Consulting, Ibadan, Nigeria

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non-violent, inclusive and effective learning environments for all' (SDG-Education 2030 Steering Committee, n.d.). The target addresses the significance of physical learning environments that are proper, sensitive and inclusive for all types of learners regardless of ability or disability status. Target 4.5 aligns with 4a, aiming among other things, at ensuring "…equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities…".

3.2 Redefining Equitable Learning Environments

'All people' captures all categories of persons, including '…persons with disabilities, migrants, indigenous peoples, and children and youth, especially those in vulnerable situations or other status'. Among key vulnerable groups requiring particular attention and targeted strategies are persons with disabilities (Ng et al., 2018). However, 'safe, non-violent, inclusive and effective learning environments' have gone, and continues to go through drastic changes. In recent times, with technological changes fostering critical transformations, human life is increasingly dependent on, enabled through, and/or controlled by technologies. These transformations also have strong implications for the future of work (Fleming et al., 2019), and requires changes in teaching and learning (Gravemeijer et al., 2017), including what constitutes learning environments.

With more advancement in technology, Education 3.0 emerged, allowing learners unprecedented access to information, eLearning opportunities, and several platforms that support synchronous and asynchronous educational connections. Networked education thus became the new order, providing extensive personalized learning opportunities that promotes truly self-paced learning, and the promotion of learners' voice and independence (Alamri et al., 2021). Learning environment have thus been transiting from within concrete walls to the internet, and is currently as much, if not more, situated in the clouds than within concrete walls.

As the world approached a new phase—Industry 4.0—with its focus on smart technology powered by artificial intelligence (AI), schools are faced with the duty of preparing students for a world of emerging cyber-physical systems. Teaching and learning approaches must to adapt themselves to provide learners with opportunities to experience and utilize these emerging technologies as part of the whole learning experience, and all aspects of learning. Schools and teachers must also take cognizance of the redefinition of learning environments that these changes are occasioning. These opportunities must be open to all types of learners, including persons with disabilities. In essence, teachers, schools and all educational stakeholders must acknowledge that learning environment is being inevitably redefined.

As emerging cyber-physical systems steadily become integral parts of various industries, the skills requirements for employees are also changing. Both LinkedIn in its review of most needed skills of 2019 (Petrone, 2018) and McKinsey in the institute's report on the future of work (Lund et al., 2021) confirm that due to Industry 4.0, and global situations in the aftermath of the COVID-19 pandemic, a good percentage of industrial activities for more than half of all current occupations could potentially become automated. Technology, especially AI, is already affecting practically every industry, and it will definitely have tremendous effects on both hard and soft skill requirements for future jobs. Today, soft skills like complex problem solving, critical and logical thinking, social skills, and teamwork skills are becoming critical requirements (Fleming et al., 2019; Tran, 2019). Education 4.0 is, therefore, about adopting new approaches to learning that are based on an understanding of future job requirements. It is an education approach whereby teaching and learning methods are aligned with future skills' need. Providing all learners, particularly SEN learners, with access to equitable learning opportunities, including eLearning, within safe learning environment, including safe eLearning environment, is becoming important, and special education must include eSpecial education.

A key approach to achieving the demands of Education 4.0 is through blended learning (Alamri et al., 2021). Many educators believed that combining face-to-face instruction with remote learning will ensure access to digital instruction for theoretical knowledge with hands-on learning for practical skills acquisition in physical classrooms. This was assumed to be the way forward, at least, until the emergence of the COVID-19 pandemic. With institutions across the world forced out of the physical classroom during the pandemic lockdown, schools had to on-board learners and teachers to virtual classrooms. Technology-Aided Instruction (TAI) took on a new dimension as instruction went one hundred percent online. Teachers and students were given no choice regarding the need to adapt quickly to new teaching and learning situations, an indication of the nature of the challenges that learners may face with evolving careers.

3.3 Challenges of eLearning for SEN Learners

With schools and teachers faced with the overwhelming task of adapting to virtual classrooms, the challenges of on-boarding teachers and students to these new platforms brought about drastic changes in student and teacher routines. Studies on the impact of this change identified among other things, mental health issues with children and young people (Singh et al., 2020). The degree of impact was found to depend on vulnerability factors like developmental age, educational status, and pre-existing mental health conditions. As such, the disruption impacts the special needs community in very drastic ways. Teachers and schools grappled with a trial-and-error process of experimentation with what works and what does not, and parents were forced to take on the even bigger role of helping with learning and managing behaviour.

3.3.1 Structure and Routines in the Education of SEN Learners

As the number of school-age special needs children continues to increase (Kuder & Accardo, 2018), more attention to their educational needs are demanded. Cai and Richdale (2020) identified the multiple challenges of learners with autism to include "*problems with handling the lack of structure and routine in college, sensory sensitivities that impacted the ability…to maintain their focus, co-morbid conditions such as anxiety, depression, and obsessive–compulsive disorder, executive functioning difficulties such as a lack of organization, and difficulty with fine-motor skills that affected writing*". Other related studies (Kuder & Accardo, 2018) also highlighted the significance of routines as a crucial element for children with SENs. The lack of structure and routine resulting from the pandemic disruption, thus, had very negative impacts on the development of these learners, and required the implementation of changes, and creation of new organizational routines to support especially students receiving special education services (Grooms & Childs, 2021). The demands on parents to 'play teacher' put higher demands and significant amounts of stress on parents in managing these learners during the lockdown (Brown et al., 2020). On their part, teachers were faced with the demands of planning and executing online instruction. Creating classrooms and lessons that are interesting, fun and effective in regular classrooms is challenging on its own, but fostering same remotely is challenging in multiple ways. This is especially more challenging within the disability community.

3.3.2 Demands of Individualized Education Plan (IEP)

Learners with special needs include individuals existing across a wide spectrum of strengths, weaknesses, interests, ages, sensory needs, abilities, and skills (Cattoni et al., 2017). As a result, working with each learner is based on his/her own Individualized Education Plan (IEP). This refers to special education programs prepared for achieving targeted goals for individuals with special needs based on their developmental characteristics, educational performances and needs (Baglama et al., 2019). These individuals not only need support for academic instruction, they may also need help with sensory experiences to self-regulate and stay focused. Some may require behaviour intervention to complete or learn new tasks, or gross and fine motor intervention to help with development. Hence, whereas teachers of a class of typical children plan and develop whole class lesson plans and presentations with some differentiations, special education teachers had to undertake the massive task of planning and designing individualised lessons according to each child's IEP.

3.3.3 Collaborating with Parents and Caregivers

Remote learning means that SEN teachers need to rely heavily on parents and care givers at home, as many of the children need specialised coaching and sensory interventions. Therefore, lessons have to be planned to instruct and guide parents and caregivers. Working with non-verbal SEN learners require direct teaching with individualized communication tools. Some SEN learners require behaviour intervention strategies to help with attention and focus while others lack the fine motor skills and coordination to manipulate the gadgets for digital learning; these needs make managing remote learning independently very challenging, and in some cases, impossible. With the pandemic curve ball threw at the world, experienced special educators have to hone their skills of 'thinking on their feet' while dealing with the unknown, and finding creative ways to fulfil the learning needs of each child, and more importantly, work in collaboration with parents.

3.4 Strategies for Remote Learning for SEN Learners

Learning from home comes with different kinds of limitations including instructional schedule and learning environment setup, re-evaluation of IEPs and learning goals, parent-teacher partnerships, and the practicality of collaboration and communication between parents and teachers. Additional issues to address include social and emotional support for SEN learners and parents and the need for new skills acquisition and/or teacher professional development. In the following paragraphs, we highlight some practical steps that were leveraged for successful remote instruction by a special educator. While every possibility cannot be captured, the issues raised highlight potential solutions that can be explored, expanded and improved upon in the classroom, by other teachers of SEN learners.

Helping parents set up the learning space and schedule at home: This is the first step towards achieving meaningful learning. This requires the understanding of parents' schedules and availability of resources. Written directions and instructional videos are useful tools for coaching parents. Video submissions of tasks and teaching done by parents on a daily basis are also necessary and required for keeping track of learning and progress.

Re-evaluation of learning goals and IEPs: Implementing school routines and schedules in the home environment is highly challenging, if not outright impossible. Lack of resources in home settings, underscores the need for re-evaluation of learning goals and IEPs. Learning goals had to be broken down into manageable tasks to suit each home environment. There is a need for goals shift from academics and cognitive work to the acquisition of self-help skills, social skills, play and communication skills.

Effective parent-teacher collaboration and communication models: Collaboration and communication between parents and teachers are crucial for effective teaching and learning. Teachers' instructional focus must therefore include coaching parents. While frustrations with the emerging demands and changes as well as slow progress cannot be ruled out, parents and teachers must learn to celebrate the smallest achievements. They must acknowledge that the standard method of individualized remote teaching may not be able to provide the intensity and flexibility of a school environment.

Minimizing learner anxiety through regular digital meetings: Daily online meets are important for social connection and emotional support for students. The sudden change in routine with school closure and disruption of structure are sources of anxiety for SEN learners; familiar faces and voices from school can be great sources of help to make students feel connected. This should be done one-to-one or in small groups. This may be challenging for SEN learners who require physical intervention to focus. Parents and caregivers had to support teachers to achieve success during these online sessions.

Providing emotional support for parents: Managing children with special needs can be mentally, emotionally, and physically exhausting for parents/caregivers, hence, parents need understanding and guidance. Where possible, parents should be provided the assurance of support while helping their children learn.

Teacher education: With the challenges of new learning environments, new resources, emerging needs for improvisation to support e-learning from home, teachers had to learn new skills. They have to learn to navigate through the many digital platforms on the internet to figure out what works for each child. They had to take into consideration the level of attention, ability, skills and support available before assigning work or implementing an online lesson. The characteristics of individual SEN learners, with respect to digital learning had to be explored and taken advantage of.

Managing expectations: This is a key issue for educators. Assignments are oftentimes not done, and online lessons may not be attended. In such situations, teachers need to review teaching plans and work with consideration for the capabilities of parents or caregivers, as well as the dynamics of the home 'learning environment'. By acknowledging that parents are not trained educators, the frustrations of teachers when goals are not being met will be lessened.

3.5 Instructing SEN Learners in Next-Generation Classrooms

The plethora of needs of the special needs community makes it difficult for many to learn through digital classrooms. Face-to-face lessons are crucial for children to develop complex linguistic and emotional skills that many of them lack. Face-to-face teaching provides the intensity and physical structure needed for learning; it is a well-known fact that "doing is learning" for early intervention as it touches these learners. However, in an ever-evolving world, educators are continually forced by changing norms to step up their games, and governments and educational institutions have to continually reinvent themselves. Pushing and supporting teachers to embrace technology and innovate in using it to execute effective lessons, and charting out means of assessments, including in SEN classrooms, is a task that must be done.

The challenges the world faced in the wake of the pandemic highlighted many previously hidden challenges in the education of SEN learners. It made many schools and governments to realize how far from achieving the SDG education goal the world is with regards to SEN learners. This calls for major adjustments in educational practices; effective pedagogies in emerging learning environments, access to resources for parents or caregivers of SEN learners for home-based instruction. Teacher training or professional development remain critical factors for success. However, current situation has also underscored the need for parent training or retraining as teacher-partners. A new definition for home-schooling thus is emerging where parents will work formally in collaboration with teachers and schools in instructional delivery for SEN learners. To be effective, this may require national policy adjustments, particularly, with regards to inclusive education and social protection. SEN learners deserve access to quality and equitable education, and national education planning has to put this at the center of efforts.

Though special schools face a demand to step up in their duties of supporting SEN learners, the time is also right for mainstream schools and institutions to expand their focus to SEN learners. Ensuring "inclusive and equitable quality education…opportunities…" and building and upgrading "education facilities that are child, disability and gender sensitive…" towards the achievement of "inclusive and effective learning environments for all" is a duty that must involve everyone from governments to NGOs, private and public schools, social groups, individuals, and other stakeholders.

3.6 Achieving SDG4 for SEN Learners

The emergence of fully online learning during the pandemic lockdown opened up many issues that were hitherto overlooked. For example, the assumption that there will be perpetual access to physical learning environments was challenged. Even with progress made in containing the virus, the experience of second and third waves, as well as emergence of mutants of the coronavirus across the globe, has made online learning to remain prevalent in many countries and across different levels of education. The current situation, if anything, is making stakeholders to rethink possibilities regarding the future of education, and practical effort to address things must be taken to heart.

Implementing effective pedagogies in fully online settings, including the potential role of emerging technologies in enabling teaching and learning is a key issue to address. Other issues are how inclusive and equitable quality eSpecial education is defined, important considerations for online education facilities that are disability-sensitive; safe, non-violent, what makes inclusive and effective e-Learning environments, and life-long e-Learning opportunities.

Implementing blended learning as the standard learning mode across classrooms is among the best options for SEN learners, and will require teachers and parents to learn to work with emerging technologies. Robots and programmes that can imitate tones of voice, show facial expressions and even help with oral motor skills by using mouth shapes are already emerging. However, while such systems can offer great help to both teachers and learners, their inability to support adaptive learning requires more focused attention from developers. Such developments can bring about the much-needed personalized learning support that SEN learners require and deserve. Integrating traditional teaching and technology has great potential to support the achievement of good results. This will, however, require (re)training of teachers and other relevant staff, as well as structured introduction to students and caregivers.

3.6.1 Inclusive and Equitable Quality ESpecial Education

Inclusive and equitable e-education entails access to the same quality of education for all persons, regardless of disability. Removing the barriers that learners with disabilities encounter in accessing e-education is critical to their effective inclusion in remote learning. Therefore, to make this a reality a few interventions have to be considered.

Teachers need training support to gain skills in the use of online learning technologies. Knowledge and understanding of the accessibility features of available assistive technology and how to use them is very crucial in selecting the best options for each learner. In addition, they must be prepared to train and/or guide parents/caregivers and learners on how to use such effectively in implementing the educational plan for the learner.

The importance of collaborations with parents/caregivers in the e-learning of their wards with disabilities cannot be over-emphasized. As such, coaching of parents/caregivers in some basic principles of teaching such learners—while recognising that they are non-professionals and have other responsibilities—is central to success. It means that such considerations of their limitations must be integrated into their training or coaching.

Availability and affordability of assistive technology could be an impediment to inclusive online learning, particularly in resource-limited settings in developing nations where such may not be available at all, or may be too expensive for parents/caregivers to acquire. The same applies to internet network with good speed, which is critical in accessing online resources. These are important issues to also address.

3.6.2 eLearning Facilities that are Disability-Sensitive

Access to social protection is very important. Poverty and disability exist in a vicious cycle, as such, many households who have family members with disabilities may also be experiencing poverty. Government policies on social protection and education must prioritise disability inclusion. In this way, parents of learners with disabilities may find it easier to acquire the necessary technologies and resources for effective e-learning for their affected children.

Some of the ways to address this can include encouraging local development of assistive technology. Since in many cases, developers are also business people, provision of assistive technology by the government in partnership with development partners. Other means are waiving of import taxes on assistive technology, and support to parents/caregivers to access other related resources such as fast internet networks and a conducive home learning environment.

In addition, procurement policies on educational equipment that support disability inclusion (either standalone or as part of social protection or education policies) should adopt inclusion. This will require the knowledge and mapping of the accessibility features as well as the types or degree of features offered by such educational equipment. It will also a practical, and good practice to motivate and patronize suppliers with disabilities when procuring assistive technology. This will in turn require an accessible or inclusive procurement procedure.

3.6.3 Safe, Non-violent, Inclusive and Effective eLearning Environments

The eLearning environment should uphold the principles of non-discrimination, safety and dignity, participation, and accessibility, and such learning environments should be assessed based on these principles.

The principle of non-discrimination ensures that learners with disabilities are not segregated to a platform other than what is offered to other learners. When services are segregated, the tendency for quality to be compromised is higher. Therefore, learners with disabilities should not be denied access to what is available to their peers without disabilities. Elearning platforms should be safe for use by learners with disabilities and their parents and caregivers. For example, such platforms should not subject learners and their parents to cyberbullying, or any form of abuse—verbal or physical.

Besides providing education in formats that are accessible to the learners, online learning platforms should encourage active participation of learners with disabilities by adopting interactive teaching methods tailored to the specific needs of individual learner with disability. The active participation opportunity enhances learning, and it is capable of achieving the educational goal of the individual.

3.6.4 Lifelong Learning Opportunities

Lifelong learning opportunities implies educational opportunities throughout one's lifetime, even after completion of formal education. Such opportunities should be applicable to all people, and are especially vital for persons with disabilities, many of whom might have missed out on formal education due to various physical or social barriers. Reducing the illiteracy level among persons with disabilities through such lifelong learning opportunities will empower persons with disabilities, and improve their access to income through exposure to personal development that enhances their job suitability. One of the costs of excluding persons with disabilities from education is reduced employability, and subsequent economic implications at the individual, family, societal and national levels. Therefore, inclusive lifelong learning has a indirect implication for reduced unemployment and underemployment rates among persons with disabilities.

As online lifelong learning opportunities continues to gain grounds globally, the coverage should be expanded by ensuring that such learning platforms are accessible, and support the inclusion of learners with different types of disabilities. Assistive technology plays an important role in the delivery of an inclusive online lifelong learning.

3.7 Conclusion

The blended model of instruction for SEN learners may not be a definite recipe for a hundred percent success, however, it is clear that human presence and physical intervention is key to motivation and development for every child. Thus, human presence, even remotely, will benefit many learners, and especially SEN learners. Online learning may present an alternative to SEN learners who have difficulties in accessing physical schools, but, it should not be considered a replacement of physical schools. The significance of social interactions and exposures that come with a physically-accessible school environment for SEN learners should not be overlooked.

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Chapter 4
The Future of Science Labs: Choosing Virtual Laboratory for Hands-on Instruction in Physics Education

Victor Kayode Ojomoh, Fatin Aliah Phang, and Nina Diana Nawi

Abstract This chapter provides a review of recent works on the future of science laboratory. It provides physics instructors with information on trends in hands-on physics instruction. Laboratory-based instruction, which has always been central to the teaching of STEM subjects, has faced obvious challenges due to multiple factors including poor funding and obsolete equipment. The emergence of COVID-19 has further forced physical classrooms, including physical laboratories, to take the back seat and highlighted the need to focus on alternatives like virtual laboratories. This chapter provides useful information for physics instructors on choosing a Virtual Laboratory for hands-on instruction in Physics Education. Though the information provided by the authors has physics instruction as a focus, the detail are also applicable in other STEM subjects.

Keywords Virtual laboratory · Physics education · COVID-19 · Online learning

4.1 Introduction

The rapid growth of science and technology, especially Information and Communication Technology (ICT) in various aspects of human life and society, continues to transform twenty-first century teaching and learning. Instructional methods that can prepare students for science and technology literacy, as well as in the skills of logical and critical thinking, creativity, and reasoning are becoming more important (Anam et al., 2019). The emerging curriculum emphasizes making students independent

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V. K. Ojomoh · F. A. Phang (✉) · N. D. Nawi
School of Education, Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia, Johor Bahru, Malaysia
e-mail: p-fatin@utm.my

V. K. Ojomoh
FCT College of Education Zuba, Abuja, Nigeria

F. A. Phang
Centre for Engineering Education, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

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and able to develop their own knowledge in an active and interactive inquiry environment (Himangshu, 2006). ‘Learning science through doing science’, has become a popular phrase for the adoption of inquiry-based learning in the classroom. New educational technologies are creating workspaces that are both functional and flexible to meet the interests and needs of the learner. The utilization of an inquiry-based learning environment in collaboration with model technology has thus proven to be highly beneficial to students (Xing et al., 2019). The authors highlight trends in hands-on physics instruction and provide information that will benefit physics instructors as well as other STEM instructors with regards to making choices for technology-supported, laboratory-based, hands-on learning.

4.2 Technology Aided Instruction (TAI) and Hands-on Learning Through Laboratory

In recent years, the applications of instructional technology and online course delivery has grown tremendously (Xing et al., 2019; Yeo & Zadnik, 2001). The impact of computer-assisted collaborative inquiry learning in STEM education has been well established in the literature (Aguele et al., 2008; Aşıksoy & Islek, 2017; Husnaini & Chen, 2019). Several studies have also shown that some students have difficulty articulating relevant concepts, making their rationale clear, and controlling their learning—all of which are needed for successful collaboration (Xing et al., 2019). Model-based inquiry is important for enhancing science topic learning. However, the application of current technologies to deliver online courses in science disciplines is limited as natural science and engineering subjects are experimental sciences that require a laboratory component to provide hands-on practices to the learner.

The physical laboratory has always been a characteristics feature of STEM instruction, and has always played crucial roles in science education (Zakaria et al., 2019; Aşıksoy & Islek, 2017; Zacharia, 2007). Science educators believe that laboratories are among the most important means of instruction in science since the 19th century, and is an essential curriculum requirement for effective science instruction (Amaral et al., 2013; Brinson, 2017). Physics is a science focused on experimental proof, critique, and reasoned discourse and experience, and the comprehension of its principles are dependent on how physical phenomena are viewed (Zacharia, 2007). Gambari et al. (2017) and Husnaini and Chen (2019) both illustrated the ineffectiveness of conventional instructional methods, and exposed a lack of comprehension of science processes and content when students were subjected to traditional lecture and demonstrations. Laboratory experiments have thus been identified as one of the most effective ways of simplifying and clarifying complex concepts (Riaz et al., 2019), and accomplishing practical learning (Khamis et al., 2018; Ghatty, 2013). Anam et al. (2019) pointed out that not all natural objects and phenomenon can be presented in classroom learning, and many are difficult to learn directly because of constraints of space, time, and equipment.

Anam et al. (2019) further submitted that, teachers rarely allow students to make observations or experiments. The results of science learning are thus, not optimal. The inadequacy of laboratory equipment is hampering the learning of science in schools and many of the equipment available are outdated or damaged, and unideal for student learning. Besides this, there is the problem of effectiveness and efficiency when implementing laboratory practical around limited hours of practical lessons within a regular 8-hour school day. There is thus a demand for unconventional, alternative laboratory environments in which students can perform necessary experiments without regard to time, space, cost, or safety constraints. The use of virtual laboratories (VLs) is one of the solutions that is being explored to address these obstacles. Using increasingly sophisticated tools, VLs support a constructivist approach to learning. Hermansyah et al. (2019) opined that VLs enable students to achieve their learning goals while avoiding the limitations of traditional laboratories. As a result, VLs are being considered in schools and universities as effective and productive resources that provide a variety of learning environments. VLs will pique students' interests, hold their attention, and act as a good motivator for learning (Booth et al., 2016; Zacharia, 2007).

4.2.1 Virtual Laboratories

According to Amaral et al. (2013), VLs are computer simulations; they contain several instructions and procedures, data analysis and presentations, and students can carry out several activities there as in real laboratories. Hermansyah et al. (2019) described a VL as a form of interactive multimedia object to simulate laboratory experiments into a computer. They deliver simulated versions of traditional laboratories and promote learner-centered learning methods in which learners are given virtual representations of real-world objects used in traditional laboratories (Faour et al., 2018). VLs allow students to learn by doing, it presents them with fun and enjoyable experiences, enabling them to explore, and maintaining an active classroom through discussions and debates. All these can help in enhancing teaching and learning processes (Oidov et al., 2012).

By speeding up or slowing down the rate of phenomena, VLs will allow students to explore conditions that cannot be checked in real time (Konak et al., 2013). They are also useful for studying advanced concepts such as relativity, and other experimentations that cannot be tested or realized in conventional laboratory environments (Booth et al., 2016; Konak et al., 2013). VLs have a visual framework for a variety of abstract concepts, as well as significant visualization and graphical analysis capabilities (Holme et al., 2015).

4.2.2 Categories of Virtual Laboratories (VLs)

Based on the types of simulations used, Harms (2000) identified four (4) categories of virtual laboratories. Table 4.1 provides detailed information on the characteristics, merits and demerits of the categories.

Table 4.1 Characteristics of various types of virtual laboratories Tan et al. (2019)

Category/Description	Type of lab solutions	Requirements	Advantages	Disadvantages
Simulations (Virtual): Classical simulations with certain elements of laboratory experiments	Laboratory by demonstration	Recording of real laboratory work needs to be produced	Easy to implement as long as a real laboratory is available for recording	Learners cannot access real-world experience through this means
Cyber Labs (Virtual): Classical simulations with elements of laboratory experiments; accessible on the web and available as JAVA-Applets	Laboratory by simulation	Simulation of laboratory work needs to be developed	Learners can participate in a simulated environment	Learners are still unable to experience handling real laboratory equipment and materials
Virtual Labs (Virtual): Simulations that attempt to model laboratory experiments as closely as possible	Virtual laboratory	A computer-based virtual laboratory needs to be developed for learners to access through a computer interface	The laboratory environment is virtually replicated for learners to operate through a computer interface	Learners can get some "hands-on" experience but only on what is available in the virtual laboratory equipment and materials
Virtual Reality Labs (Virtual): Simulations that are more real and able to provide better lab experience and learning outcomes (Falode & Onasanya, 2015).	Virtual reality (VR) laboratory	Virtual reality (VR) laboratory environment needs to be developed for learners to access often through a computer interface	Better than virtual laboratories; the environment is more real, leading to better laboratory experience and learning outcomes	More work is needed to produce R labs, and learners still don't have access to real laboratory equipment and materials

VLs are becoming more widely used as teaching tools in a variety of settings. However, creating a virtual laboratory for teaching and learning, is a challenging task that involves expertise in a number of fields including interface design, visualization, and pedagogy. It entails the development of texts, images, 3D environments, and interactivity, as well as programming and animation.

The development of a VL, as well as its implementation in a laboratory exercise for learning requires the development of a constrained, scripted series of experimental procedures, as well as the knowledge of the three TPACK (technology, pedagogy, and content knowledge) domains (Muthupalani & Achuthan, 2017). Although both traditional laboratory (TL) and VL may require essentially identical laboratory procedures, in VLs, an experiment is performed by the learner, while a presentation is performed by the instructor (Wästberg et al., 2019).

4.2.3 Physics Education Technology (PhET) Virtual Laboratories

VLs are one category of the many computer-based innovations that are attracting a lot of attention in terms of promoting STEM learning and vocational skills. They are becoming popular across a broad range of disciplines. It is however important that the validity of learning technologies be established by ensuring that any technology achieves what it claims to achieve before using it. The aim of a virtual lab is to provide students with hands-on experience that will contribute to learning (Lampi, 2013). The PhET project is one of many platforms that have built and tested a number of highly successful simulations. Most topics discussed in a standard introductory physics course are covered in the PhET project's approximately 60 freely available simulations.

With PhET as an example, we describe some important parameters to take into consideration when selecting a VL for science instruction:

- Level of fidelity
  This is the degree to which a simulation imitates or amplifies the 'truth' or reality. Howard, (2018) submits that a person's actions are based on their intelligence, competence, and success. The level of fidelity in a simulation experience increases as a student's knowledge, competence, performance, and action improves. Simulation-based curriculum techniques may be used to organize learning environments where the focus is for students to enhance or gain competency. The higher the fidelity of the system, the more a student does, and therefore, the more opportunities for learning is available. In a simulation, the struggle with recreating these experiences may be with realism and fidelity (Howard, 2018)
- Levels of user interaction and exploratory freedom:
  User interfaces are becoming more intuitive as they adapt to the needs of individual learner, and continue the trend toward more individualized learning and increased learner autonomy (Freitas & Neumann, 2009). The use of an exploratory learning

model that encourages teachers to reconsider how they teach in 3D and immersive spaces will promote greater user interaction. In these spaces, learning sequences and experiences are choreographed to support peer interactions and exchanges. The user can be provided with the requisite stimulation by making the simulation relate to the real world and using appropriate animation and interactivity.

- Features for simulating physical manipulatives:
  Physical simulation attempts to simulate real-world processes in the laboratory so that the data can be used to solve real-world problems. Since it allows extremely realistic animations, physical simulation techniques have been commonly used in computer graphics. It includes techniques for manipulating the behavior of physically-based object simulations. The goal-oriented control scheme allows users to control and redirect animations or artifacts interactively while also ensuring that the edited result is physically conforming. The more the features in a VL for simulating manipulatives, the better the learning experiences they can support. This specific attribute may underscore the significance of haptics in virtual environments.
- Opportunity for open-ended experimentation:
  In an open-ended laboratory, students are free to design their own experiments rather than follow pre-determined guidelines from a laboratory manual. This will challenge students to think critically, creatively, and 'outside-the-box'. It will also encourage students to learn independently by providing them with a platform to be innovative and creative in designing and executing their own experiments.
- Level of accessibility and usability
  Regardless of disability status, all learning materials, whether created or adopted, must be accessible to all types of students. As a result, usability should be a major consideration when choosing VLs. When considering a VL platform for instruction, important consideration in terms of accessibility will include a critical review of the usability documents provided by the developer, and the user-friendliness of the system.
- Level of scaffolding
  In many ways, an expressive VL promotes the scaffolding of students' learning in many ways. It automates repetitive calculations that would otherwise confuse students or restrict their explorations to very basic instances. The visualization resources aid in the connection of quantitative findings to conceptual understanding. It guides students through the process of analyzing, testing, and improving their designs. Based on highly inspiring real-world examples, it lets them find out what modeling assumptions are acceptable, and what numerical values make sense, and it proposes procedures for how designs can be improved (Akar et al., 2015).

4.3 Conclusion

When compared to traditional methods, model-based inquiry with virtual practical laboratory pedagogy is more effective in improving students' scientific inquiry skills than conventional methods. It supports significant improvements in process skills, systematic skills, learning attitude, communication skills, and reflection skills. VLs not only allow instructors to change the standard curriculum, but also allow students to create their own programs and recognize implementation issues (Shyr, 2010). Studies of VL usage in high school science indicate that VLs improve students' understanding of physics concepts (Gunawan et al., 2018; Suranti et al., 2018).

Anam et al. (2019) noted an increase in students' interest in learning when presented with VL media. It showed that students are more active, tend to be more curious, and want to try. Combining the directed inquiry model with a VL is still uncommon, particularly when it comes to students' conceptual understanding of science process skills. In addition, a deeper understanding of the efficacy of this learning model for science process skills, as well as comprehensive data and discussion are needed. More thorough investigations are needed to demonstrate the importance of directed inquiry learning models in VLs for students' conceptual understanding. This knowledge will serve as a benchmark for technology-enhanced learning (Gunawan et al., 2018).

As more learning moves online, and VLs become part of everyday learning, instructors will need to address the challenge of choosing the most effective VL systems for promoting hands-on learning. This chapter highlights important factors that STEM instructors need to consider in making such choices. These factors include the level of fidelity, user interaction and exploratory freedom supported by the VL. The features present for simulating physical manipulatives, and the opportunities provided for open-ended experimentation and the levels of accessibility support for scaffolding are also important factors.

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Chapter 5
ICT Masterplans in Education: Singapore's Reform Efforts to Engage in a Post-COVID World

Uma Natarajan and Kumar Laxman

Abstract In 1997, Singapore committed to reforming its education system with the aim of preparing young Singaporeans for changes in the coming decades. The national Information and Communication Technology (ICT) Masterplans were one of a series of reform initiatives that began with a focus towards change in teaching and learning in Singaporean classrooms with technology integration. In this article, we summarize the four ICT masterplans implemented since the "Thinking Schools Learning Nation" (TSLN) initiative. Following the introduction of the first masterplan for ICT in education, the Ministry of Education ensured that schools had infrastructure, leadership and necessary teacher training to successfully implement the initiatives. The descriptions of the implementations are valuable lessons for other national systems in the region and beyond that are seeking improvement in their education systems through technology-enhanced learning and ICT.

Keywords Singapore · ICT · Masterplans · Technology · Reform · Blended learning

5.1 Introduction

Singapore continues to rank among top ten global cities in the world for human development based on indicators of health, education and income. The country is an excellent case study of how the government and its people respond constantly to the incessant changes in globalization in the current volatile, complex and uncertain world. Education has been recognized as a critical sector, and Singapore has formulated and developed a number of national Information Communication Technology (ICT)-focused schemes to increase ICT awareness and literacy (Koh and Lee, 2008).

U. Natarajan
National Institute of Education, Nanyang Technological University, Singapore, Singapore

K. Laxman (✉)
University of Auckland, Auckland, New Zealand
e-mail: k.laxman@auckland.ac.nz

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Against the backdrop of a highly globalized economy that is increasingly knowledge-based, Singapore recognizes the need to foster innovation in educational delivery. In addressing these concerns, several educational policies and initiatives have been launched. An example is the TSLN vision plan. Singapore has implemented four ICT-in-Education masterplans over the last 20 years. The TSLN spiraled into a number of initiatives in subsequent years with widespread propagation of ICT in schools (Reyes & Gopinathan, 2015). This chapter provides a description of Singapore's national ICT Masterplans since 1997, summarizing their aims and achievements as well as the impact on the education, economic and social dimensions of life.

5.2 Singapore's First Three ICT Masterplans

The first ICT Masterplan (MP1) was launched in 1997 with a budget of $2 Billion SGD. The objective was to lay a strong foundation in ICT for all schools in Singapore in terms of technology infrastructure and education capacity (MOE, 1997, 2002). The target was to begin teacher capacity building for technology tools so teachers were comfortable to begin using the computers. Networked access for entire schools with Internet and an ambitious 5:1 pupil to computer ratio was planned. Towards the end of the first phase in 2002, Singapore was ranked second in the world, after Finland, in the then Global Competitiveness Report (2001–2002) for the availability of Internet access in schools (Porter et al., 2002). Between 30 and 50 hours of teacher capacity building was planned for every teacher in the system over a one-year period, which was considered remarkable by international standards. A policy was established that entitled each teacher to 100 hours of sponsored professional development per year. Teachers had to complete a few modules of just ICT training over 30–50 training hours in the initial stages of the masterplans. MP1 was implemented in three phases, starting with 22 schools in phase 1, followed by extension to all schools by 2002. At the end of MP1, all schools were equipped with necessary physical hardware and infrastructure to prepare them for ICT-based education. Teachers had been trained with basic ICT competencies and had accepted the reality of an educational paradigm that is ICT-powered. It also provided a blueprint for the integration of ICT in education as a strategy for equipping students with the requisite ICT skills to empower them to meet the challenges of globalization and technological advancements (Lee & Koh, 2008).

ICT Masterplan 2 (MP2) followed in 2003 with a budget of $600 million SGD, where a key focus was the establishment of structures, such as tiered support for schools at various levels of ICT usage for Teaching and Learning, to promote a culture of exploration and innovation in education. During this phase, a set of baseline ICT standards that every student in the system had to attain at certain milestones of education (e.g. by Primary 3 or Secondary 3 level) was also implemented. New and alternative pedagogies such as inquiry-based learning and problem-based learning emerged. ICT-related products from the students included blogs, e-portfolios, animations and videos where they demonstrated what they learned in class. It is important to note that all of these were happening concurrently with the rise of socio-technological innovations such as Wikipedia, YouTube and the immersive world of Second Life. At the end of MP2, a sustainable framework for the sharing of digital educational resources and ICT-based pedagogical practices had been put in place. Teachers embarked on a range professional development programs in the form of workshops, field work, collaborations with industry partners, etc.

The third Masterplan began in 2009. Efforts to enhance ICT integration within the curriculum, pedagogy and assessment in order to keep pace with the 21st century competencies evolved (MOE, 2008). The use of ICT was encouraged not only for building technology literate citizens but also to instill higher order thinking, communication and collaboration skills. A push towards varied ways of learning using ICT was encouraged—self-regulated learning, individualised instruction, anytime-anywhere learning, deeper learning, collaborative learning etc. Teachers were also encouraged to share best practices and learn from their peers. The Ministry continued to focus concurrently on leadership capacity building for implementing ICT based plans. By 2014, several initiatives like Fasttrack@school, Edvantage, and eduLab had been implemented and evaluated.

In 2019, 98% of resident households in Singapore reported they had access to Internet at home (Infocomm Media Development Authority, 2021). The evaluation study of the Third ICT Masterplan (MP3) in Education revealed that Singapore teachers had been using various tools with social media affordances such as LinoIT, Wallwisher, Glogster, MindMeister, Google Sites and Edmodo over the last five years to support self-directed learning and collaborative learning among the students (Tan et al., 2013; Seow et al., 2020)

To date, four ICT masterplans have been successfully implemented, namely, Masterplan One (1997–2002), Masterplan Two (2003–2008), Masterplan Three (2009–2014), and Masterplan Four (2015–present).

5.3 Two Decades of Education Technology

The Fourth Masterplan for ICT in Education (MP4), is meant to build on the experiences and successes of the preceding three Masterplans, and it therefore focuses beyond self-directed and collaborative learning (SDL and CoL) to the overall curriculum (MOE, 2015). MP4's focus is to use ICT productively to develop knowledge through subject mastery, skills through 21st Century Competencies, and attitudes through responsible digital citizenry. The alignment of this fourth masterplan follows MOE's direction towards student-centric and value-driven education, including in the areas of cyber-wellness and responsible and safe media literacy. MP4's vision is to nurture "Future-ready and Responsible Digital Learners". The two enablers associated with this objective are: (i) Teachers as Designers of Learning Experiences and Environments, and (ii) School Leaders as Culture Builders. Deeper ICT Integration in curriculum. Assessment and pedagogy, sustained professional learning, translational research and innovation and teacher capacity development are the four approaches within MP4 to achieve the desired vision.

5.4 The Student Learning Space

The Student Learning Space (SLS) is yet another technology initiative that was rolled out in 2018 by the MOE. SLS is an online learning platform that permits all students from primary to pre-University levels to have equal access to good quality curriculum-aligned resources. The system allows teachers to conduct lessons both synchronously and asynchronously. In preparation for the development of 21st-Century Competencies (21CC), the SLS enables learners to be independent, and self-directed, and allows them to personalize their learning according to their needs and interests. Teachers have a range of tools that they can utilize to design meaningful learning experiences. They can use the tools for lesson preparation, lesson enactment and evaluation.

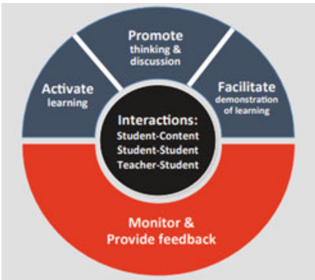
Assessment tools are built in to assist teachers to monitor students' comprehension regularly and provide targeted interventions, as well as appropriate feedback to address the gaps in understanding. The platform also facilitates sharing among teachers and educators across schools. Teachers can enrich their lessons by linking to external videos from YouTube or TED talks, in addition to an MOE library of resources. They can also use other tools and applications which can be integrated into the platform with ease. The hope is that the resources within the SLS will help in leveling the playing field for all students in Singapore by providing access to quality learning resources. Students can access these resources through school networks and the computer labs in schools. Table 5.1 shows the respective structure of Singapore's student learning space pedagogical scaffold.

The SLS was very timely in view of the COVID-19 pandemic in helping Singapore embark on home-based learning swiftly without students facing any interruption to schooling. Table 5.2 shows the roles of student, teacher and technology in active learning processes.

5.5 Impact of Covid-19 on Learning in Classrooms of the Future

The COVID-19 pandemic has disrupted education systems globally and countries around the world are grappling with the many challenge of restoring normalcy in teaching and learning for schools. There is a huge opportunity to re-imagine and transform the education systems in a post-COVID world. Technology has always been considered important as part of the 21st-century skills but most countries have also seen that technology itself presents a huge disparity between those who are

Table 5.1 Student learning space pedagogical scaffold

<table>
<tr><th>Lesson preparation</th><th>Lesson enactment</th><th>Assessment & feedback</th></tr>
<tr><td>Phase 1 Establish learning outcomes</td><td>Phase 2 Design & facilitate active learning with technology</td><td>Phase 3 Assess quality of learning</td></tr>
<tr><td>Q1. What are the key concepts essential to my students' understanding of this topic?
Q2. What are the skills, values and attitudes, including 21CC, that are important for my students to develop?
Q3. What are the success criteria that can inform me that my students are learning?
Q4. What evidence would I use to know my students are learning?
Q5. What is the pedagogical approach in relation to the iden8fied learning outcomes?
Q6. What are technologies that can be harnessed to:
• Promote learning of the key concepts;
• Develop skills, values and attitudes, including 21CC;
• Check for student understanding;
• Monitor student learning
• Provide feedback?</td><td>Q7. How would I design learning activities that promote the following active learning processes with technology?
• Ac8vate learning
• Promote thinking and discussion
• Facilitate demonstra8on of learning
• Monitor and provide feedback
Q8. How would I facilitate student-content, student-student and teacher-student interactions for active learning?
Active learning with technology

</td><td>Q9. How did the evidence of learning with technology show that learning outcomes were met? Q10. How effec8ve is the design of the learning ac8vi8es with technology?</td></tr>
</table>

Source: Education Technology Division, Ministry of Education, Singapore

connected and those who are not, during the pandemic. The gap between what skills children learn and what they need is getting wider in today's post-pandemic world.

5.6 Technology in Teaching and Learning Going Forward

Singapore has embarked on a journey to step up efforts to focus on students' strengths and maximise opportunities for each individual child in school. Technology can enable the creation of personalized experiences, as well as assess based on individual learner potentials. Blended learning, where a mix of face-to-face and online modes that includes a day of home-based learning (HBL), is being introduced in Singapore schools from 2021. This is the next tier of policy changes in the system involving ICT, and the SLS infrastructure is being used to implement it. The two decades of ICT Masterplans in Education have evolved from a strong focus on "Foundation building"

Table 5.2 Roles of student, teacher and technology in active learning processes

Active learning processes	Role of student	Role of teacher	Role of technology
	Interactions between teacher, student & content		
Activate learning How will students' focus and interest be oriented towards the learning objectives?	• Set own or group learning goals • Connect prior knowledge to the task	• Clarify learning objective and success criteria • Design trigger activity to elicit students' prior knowledge	1. Multimodal representation of a concept e.g. multimedia resources, websites, podcasts, webcasts, anima8ons, videos 2. Facilitate planning, participation and development of ideas e.g. wikis, email, online calendar 3. Task environments that represent and simulate real-world problems, situations and contexts e.g. microworlds and simulations, virtual/augmented reality, role-play simulations, serious games and immersive environment, manipulatives to facilitate problem-solving 4. Analysis and synthesis e.g. graphic organisers, mindmap, spreadsheets, computational tools or software 5. Iterative discussions e.g. web conferences, live or asynchronous online chat or forum 6. Collection of data e.g. data-logging devices, online survey 7. Access to information for research e.g. online libraries, databases, search engines Access to learning partners or experts e.g. email, web conferencing, social media tools, online learning network, webinars, online courses, MOOCs 8. Creation of digital products e.g. video editing, infographics, slideshows, animations, website, blog, e-books 9. Tracking and assessing e.g. clickers to gather responses to ques8ons, online quizzes, classroom management system 10. Communicate feedback e.g. email, web conferencing, social media tools, annota8on tools
Promote thinking and discussion How will students think about ideas and concepts? What skills and processes will students perform? How will students build on their current understanding?	• Engage in thinking through discussion, negotiation and meaning making Use peers' and teacher's ideas and concepts to refine own understanding	• Design tasks to connect, challenge, deepen or extend students' thinking • Provide thinking routines or scaffolds • Get students to share their ideas and concepts • Teacher articulates his/her ideas and concept	
Facilitate demonstration of learning How will students demonstrate their understanding and new learning?	• Ar8culate understanding of concepts • Demonstra8on of skills • Apply learning by creating a digital product	• Design performance tasks for students to apply their learning in various ways	
Monitor and provide feedback How can students' learning be advanced?	Provide feedback to peers • Use feedback from peers and teacher to refine own understanding • Reflect on goals and learning process	• Check for understanding using students' works • Give timely and targeted feedback • Provide opportunities for feedback from peers or experts • Ensure learning objectives and success criteria are met	

towards the "strengthening and scaling" of pedagogically sound practices. As ICT is increasingly woven into teaching and learning interactions, the implementation of ICT Masterplans would necessarily be more complex and diverse.

The culture of sharing amongst educators has been carefully nurtured through the Masterplans, and this needs to continue so that best practices can be effectively spread within the system. MP4 has envisioned the strategy of strengthened Networked Learning Communities (iNLCs) for Technology in Learning to sustain professional learning among the pre- and in-service communities. In the new culture of learning, the divide between formal and informal learning becomes blurred. Much can be learned from interaction with peers, everyday activities and the social media. Schools should recognise this and perhaps alternative assessment methods can be considered to incorporate student learning in their informal activities.

5.7 Singapore as a Smart Nation

The Smart Nation initiative is about creating new opportunities in the digital age, and transforming the way people live, work and play, so that Singapore remains an outstanding green global city (Government of Singapore, 2020). The ICT Masterplans in schools following the TSLN vision was one integral element. Today, teachers in Singapore appear much more comfortable with technology in classrooms, using it for both teaching, administration, as well as their own learning. Beginning with a vision, and a leadership to implement the vision, enabling infrastructure was followed by curricular changes. Encouraging teachers to move away from a direct-instruction to a technology-integrated inquiry-oriented pedagogy was a huge challenge, but not impossible.

Within a competitive environment, it is important that workers are able to work collaboratively in teams, think critically and innovatively, add value to existing knowledge and cultural artefacts, and be competent in the use of ICTs. Such demands have led many developed and developing countries to embark on reforming their respective education systems (Day & Sachs, 2004).

It is often assumed that high-stakes tests in Singapore inflict pressure on teachers' pedagogic styles to "teach to the test", resulting in rote learning. However, examples from various future school interventions have demonstrated that different types of assessments at classroom level have helped children to acquire the content knowledge, inquiry and creativity skills, and 21st century competencies needed for the 2030 workforce (Norris et al., 2016). Other case studies have been reported on how innovative curricular designs in science classrooms that incorporate elements that help in bridging formal and informal student learning spaces using seamless mobile technologies have been successful (Looi et al., 2016).

5.8 Conclusion

Singapore education system continues to thrive as one of the best public education systems in the world. The TSLN initiative and the accompanying ICT Masterplans were huge endeavours that attempted to transform the Singapore education system. It is important to mention that OECD's 2015 report shows that there has been no appreciable improvement in student achievement in international assessments in reading, mathematics or science, on average, in countries that have invested heavily in ICT for education. However, the argument here is that Singapore has achieved to implement ICT on a wide scale in schools so that technology can help build an inclusive and accessible society. The Masterplans have addressed digital and information divides through a sustained agenda of ICT education in schools, where there are opportunities and avenues for every student to engage and participate in the digital economy. Self-directed learning and some foundational life skills like time management, self-regulation and persistence need to be taught to students to enculturate a spirit of lifelong learning. According to a New York Times columnist (Friedman, 2020): "the most critical role for K-12 educators, therefore, will be to equip young people with the curiosity and passion to be lifelong learners who feel ownership over their education".

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Chapter 6
Status of Equitable Digital Learning Opportunities in the Pandemic Era: The Nigerian Experience

Sani Ahmed Sambo

Abstract The chapter highlights challenges of pandemic-forced, internet-based learning in developing nations. Through a review of high- and 'low-tech' alternatives, including television, radio and social media and 'no-tech' solutions during the pandemic lockdown, the chapter highlighted how technology access and use for learning enhanced the ever-widening gap between privileged learners and their underprivileged counterparts. The review called to question the assumed potential of technology to bridge equity gaps, and solve the problem of equitable and quality access to education. The implications of the status of online learning for the achievement of SDG4, and graduate competitiveness were also discussed among other issues.

Keywords Nigeria · Equitable learning opportunities · SDG4 · Online learning · Pandemic · Low-tech solutions

6.1 Introduction and Background

Education has been severally described as the instrument per excellence, and the most indispensable tool for the overall development of any society. This may suggest why every nation, regardless of its development level strives to educate its populace as a careful, and deliberate effort to prevent itself from the devastating consequences of an ignorant society. The agenda for global transformation is traceable to the much-celebrated Sustainable Development Goals (SDGs) adopted by the United Nations (UN) General assembly in 2015. Goal #4 of the 17 SDGs specifically aims to 'ensure inclusive and equitable quality education, and promote lifelong learning opportunities for all'.

Inclusive and equitable education refers to education for all without any form of discrimination. In its 'Education 2030: The Incheon Declaration and Framework for Action', UNESCO (2016) holds that inclusion and equity in and through education is the cornerstone of a transformative education agenda, hence its focus in dealing

S. A. Sambo (✉)
Department of Curriculum Studies and Educational Technology, Usmanu Danfodiyo University, Sokoto, Nigeria

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with all forms of marginalization, exclusion, disparities and inequalities in terms of access, participation or learning outcomes. It thus declared: "No education target should be considered met unless met by all".

Due to many factors, attaining this level of equity, inclusivity and quality in education has always been a great challenge. The Nigerian experience prior to the emergence of COVID-19 had been such that education opportunities were connected to income level, and access to quality education differs along the lines of students' socio-economic background. Therefore, students whose parents are willing and capable, have easy access to better learning resources. This category of students usually attend private schools, colleges and universities. Underprivileged students from lower socio-economic background go to public schools where they apparently lack better opportunities (Obiakor & Adeniran, 2020). This inequality is not limited to developing economies like Nigeria; it has also been noted in many developed nations (Huang et al., 2020). For example, in 2019, England had over 25% of its young people from state-funded schools categorized as disadvantaged, with a widening gap existing between those disadvantaged students and their peers (DfE, 2019a, 2019b).

6.2 Global Education During the COVID-19 Pandemic Lockdown

The year 2019 is one of the few in the current century that left the entire world with indelible memories of peculiar challenges. The outbreak of the COVID-19 pandemic demanded drastic changes in all sectors and facets of human lives. These demands were exceptionally challenging for developing nations. Education, the fulcrum for development in all other sectors, specifically faced an unprecedented threat as nations were forced to go on lockdown and schools at all levels shut their doors as part of the deliberate efforts by governments across the world to contain the spread of the coronavirus. In line with global expectations and to maintain safety of human lives, the government of Nigeria joined other nations to shut down all institutions of learning in order to curtail the spread of the coronavirus.

The closure of educational institution was however challenging as physical closures were meant to be met with an effort towards migration to virtual learning environments. Teachers, instructors and lecturers had to quickly pick up e-teaching skills, and several online platforms offered video-conferencing solutions that did their best to rescue the situation. While the solutions may not be perfect, they provided the best options for the world during that era, and enabled continued teaching and learning with both learners and instructors connecting to learning spaces from the safety of their homes. The gradual, global shift from traditional learning processes to modern instructional techniques quickly transitioned to fully online-based, technology-supported learning. The rate of online classes, seminars, workshops, conferences and meetings rose to a level the world has never witnessed before and education, at all levels became totally reliant on technology (Soni, 2020).

As nations began to explore different initiatives with regards to education at all levels, the Chinese Ministry of Education launched what it tagged "Disrupted classes, Undisrupted Learning", an initiative that provided flexible online learning to over 270 million learners from the comfort of their homes during the lockdown. In India and other Asian countries, many educational institutions that were hitherto reluctant to change their traditional pedagogical approaches were forced to shift entirely to online teaching and learning (Dhawan, 2020). Zoom classroom became a household vocabulary, and 'being in class' became synonymous with sitting in front of the PC or a phone screen.

6.2.1 Education in Developing Nations During the Pandemic Lockdown

In many developing nations, basic infrastructures, including power, internet connectivity and necessary electronic gadgets were beyond the reach of the average citizen. The attendant challenges of school closures were thus enormous, particularly for the under-privileged. The same group of learners previously had limited or no educational opportunities beyond the four walls of the traditional classroom. Acknowledging the existence of this digital divide is the recognition of the role of "hi-tech, low-tech and no-tech solutions" to digital education in order to guarantee equitable learning opportunity for all children across the globe.

Although several measures were put in place by both the national government and other stakeholders to contain the enormous disadvantages of school closure, the situation no doubt highlighted the pre-existing differences among Nigerian children based on social class and economic status. It enhanced the combined negative effect on the learning opportunities of the less privileged, especially those in the remotest rural areas. Other than online learning therefore, improvisation in any useful form became the most appropriate alternatives to provide a 'somewhat equitable education' to Nigerian children.

6.2.2 Hi-tech and Low-tech Lockdown Learning Solutions in Nigeria

Among the initiatives explored in Nigeria were teaching and learning through various online platforms for those with access to digital learning opportunities, and the use of traditional electronic media, including radio and television as low-tech solutions. Some volunteer teachers and non-governmental organizations (NGOs) also rose to the task and made tremendous contributions in this regard. Parents and caregivers were also reported to have aided children through home-based teaching (Oladunjoye, 2020).

While this effort was regarded as timely and commendable, it also underscores the deep digital divide linkable to socio-economic status and geographical locations of school children. Children in remote and rural areas were inadvertently excluded from leveraging high-tech solutions, and many were faced with no-tech solution for continued instruction. The much advocated equity and competitiveness in learning opportunities for all citizens was thus further called to question. The irony of the situation lies in that technology integration has been touted as a potential solution for removing geographical and physical divides between learners and learning opportunities. It was considered a factor for the achievement of 'equitable educational opportunity for all'. It however became unfortunately evident that with technology, some children had much better, and in fact, extreme advantages, over others, as always. Rather than becoming a solution that promotes equity, technological access further widens the learning gap between the privileged and the underprivileged. This situation also brings to the fore the question of if in educational opportunities is achievable at all.

6.3 Examples of Low-tech, eLearning Options During the Pandemic

Instructional delivery through e-learning in public institutions in Nigeria during the COVID-19 pandemic was first affected by access to ICT resources, then lack of skills on utilization of the tools among both teachers and students. Access to good internet, PCs and other tele-conferencing devices, digital library, and classrooms accessible from homes, were non-existent. In addition, there had always been an acute shortage of teachers who can adequately handle technology tools to facilitate e-Learning (Mac-Ikemenjima, 2005; Jegede & Owolabi, 2003). Thus, in the wake of the pandemic, and the demand for swift migration to digital instructions, social, geographical and competency factors re-echoed the pre-existing social and educational inequalities in the delivery of instructions to Nigerian citizens.

Public schools in many states did not use modern or emerging technologies to teach during the lockdown. The most prominent states with e-Learning platforms were Ondo, Ogun, Edo, and Kaduna states (FME, 2019). This is linked to an initiative of the Federal Ministry of Education to equip students for better performance. Other Schools with good opportunities are Unity Secondary Schools which are managed directly by the Federal Government (Agbele & Oyelade, 2020). These schools enjoy privileges of dedicated virtual learning platforms. Privately-owned primary, secondary and tertiary institutions also have dedicated e-Learning platforms and were thus able to mitigate the effect of the lockdown.

Availability and access to digital learning platforms and utilization are however, different issues, and the transition to digital learning was very challenging for both learners and instructors in the less privileged group. Children in rural communities were totally left behind in these digital transitions due to lack of access to digital tools

(Amorighoye, 2020). This factor inspired the Federal Ministry of Education (FME) to explore low-tech alternatives like radio and television as well as social media to support learning.

6.3.1 Television Lessons

Teaching through the television focused mainly on Nigeria's high school curriculum as the period of the pandemic coincided with the time preparatory to the senior secondary certificate examination (SSCE) conducted annually by the West African Examinations Council (WAEC). Instructors were provided by state governments from among most qualified secondary schools teachers and some tertiary institution lecturers. The author was among the volunteer instructors who taught English via Radio and Television in Zamfara state. Some Non-Governmental organizations (NGOs) also sponsored similar programs for English, Mathematics, Biology and other subjects.

The television medium supported multimedia learning opportunities in the absence of affordable, accessible and reliable internet connectivity and gadgets. The audio-visual mode supports a reasonable level of comprehension through the use of body language, gestures, demonstrations and images. Key challenges however revolved around erratic power supply, as airing times for the learning program on TV might coincide with periods of no electricity supply. There is also the issue of transmission frequency coverage where many towns and villages that are far from capital cities (where transmission stations are usually located) cannot receive signals to watch the lessons on TV.

The asynchronous nature of the delivery also makes it a one-way affair, with no opportunities for either learners or teachers to get any form of feedback. There was no way for the instructor to facilitate learning through instructional scaffolding or problem-based learning approaches or to check up on learners to be sure they are being carried along, and that learning is taking place.

6.3.2 Radio Lessons

Instructors were provided by state ministries of education, with enormous contribution from NGOs. They taught English, Mathematics, Biology and other subjects. Because of the wider coverage of radio-frequencies, this option provided access to learning at reduced cost for a greater population of learners including those in the remotest rural areas. However, unlike TV, it is totally reliant on audio output for instruction, and learners cannot have the advantage of more effective learning opportunities provided when audio is combined with visuals. Audiovisuals in education have direct implications for the visualization of abstract concepts and it directly affect conceptual understanding (Nicolaou et al., 2019). In addition, studies on the neural effects of gesture-based instruction has shown that learning through a combination of gesture and speech is more effective than learning through speech alone (Wakefield et al., 2019). Presentations may also get interrupted by power outages if batteries or other alternative power sources are not available to learners.

The wide implication of this is that alternative or low-tech support for education through traditional radio and television further underscores an ever-widening gap in access to qualitative education between citizens based on their geographical location and socio-economic status. The situation is worsened by the fact that even a proper TV set is beyond the reach of some underprivileged students.

6.3.3 Social Media Lessons

Social media has proven its relevance in promoting a new era of social learning, and as an alternative platform to foster online learning in developing countries. A relevant study (Sawahel, 2020) examined social media usage in sustaining formal academic communication in developing countries as response to COVID-19 in higher education. It rated Facebook and WhatsApp as the most commonly and effectively used platforms for formal teaching and learning in higher institutions in Egypt without formal digital Learning Management Systems (LMS) during the pandemic lockdown. The study further showed that most faculty members used Facebook or WhatsApp as the only tool for academic interaction because students were neither familiar with, nor trained on how to use digital platforms such as Zoom, Google Meet, Google Classroom, etc. The situation was similar in Nigeria, although institutions that utilized social media were mainly private schools, colleges and universities.

The foregoing underscores the significance of pre-existing, and long-term, wide socio-economic gaps as the main underlying factor for the digital divide observed during the pandemic. It has remained the bane of efforts towards enabling inclusive and equitable quality education. The COVID-19 pandemic lockdown and subsequent school closures proved that even technology-mediated efforts were also affected by the persistent imbalance in the social structure of the Nigerian society. Inevitabilities of postmodern life, including skill demands of 21st century workplace are such that make digital skills acquisition an absolute necessity for all citizens no matter their peculiarities. Again, with global demand for functional and skilled-oriented workforce for Industry 4.0 labour market, these types of challenges have implications for graduate competiveness. Unequal access to digital skills and tools could further worsen the already wide socio-economic and educational disparities in such a way that future job opportunities might also be a preserve of already privileged citizens.

The consequences of this are enormous, and by extension, also have implications for both national revenue generation through education and tourism on one hand, and loss through education tourism to other nations where technology and digital learning opportunities are available and functional on the other.

6.4 Education in Next-Generation Classrooms and Schools

Serious limitations in Nigeria education delivery became obvious and conspicuous during the pandemic lockdown when the Federal Ministry of Education resorted to the use of eighteenth-century tools to deliver instruction to twenty-first-century learners, especially in Northern Nigeria. This was at a time when other nations were evaluating initiatives based on emerging technologies and planning for the future of a world facing Industry 4.0. National education systems across the world were migrating to more sophisticated, effective and efficient internet based e-learning tools and platforms. Definite programmes, focused initiatives already put in place were being reviewed to make them more compliant for the postmodern world. It is therefore concerning that Nigeria does not appear to be making concerted efforts at mapping out any workable and reasonable action plan. The nation may fail to provide its young people the much needed opportunity for next-generation learning experiences that will empower them to compete favourably in the twenty-first-century global marketplace.

According to CCSSO (2010), such learning experiences should focus on six critical attributes including world-class knowledge and skills, performance-based learning, personalized learning, comprehensive systems of support, anytime-anywhere learning and student agency which are all required in the current changing world. There is clear indication that education delivery process in the immediate future will rely heavily on online, web-based, open, computer-assisted, blended, and mobile learning among others. Any educational provision which falls short of a recognition for the critical attributes outlined will only leave Nigerian children and youths with limited digital skills and general knowledge that will put them at a disadvantage in comparison with their peers in other parts of the world.

The current unrest that is ravaging the nation, and the constant state of insecurity has rendered the nation economically impoverished; it has kept national income at an all-time low, and unemployment at an all-time high. Foreign investments is almost non-existent and the nation continues to sink deeper into debt. These are pointers to the national disaster that a population of disadvantaged children and youths can become over time. Failing to provide quality education will eventually endanger the privileged few as an aggravated level of ignorance comes with attendant repercussions that may present itself as various forms of criminality.

6.5 Conclusion

Nigeria as a nation needs to face up to the imminent repercussions of the current education situation. Nothing should be spared in terms of effort, resources, time, policy commitment and action to arrest the problematic digital and economic divide threatening the future of the nation. Efforts to provide improved access to the Internet in public educational institutions, and affordable gadgets required for digital instruction at little or no cost are important issues to consider. A wide range of alternative sources of energy and internet facilities should be explored especially in rural areas, to enhance accessibility and improve access to equitable educational opportunities for all. Critical stakeholders, including state and federal governments, ministries and agencies of education, NGOs as well as well-meaning individuals need to enhance partnership and synergy to make relevant contributions in terms of resources funds, training and policies that can ensure the realization of enabling atmosphere for teaching and learning in both physical and virtual space.

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Chapter 7
Reducing Cognitive Load in Emerging Digital Learning Environments Through Peer Instruction

Bosede I. Edwards, Nurbiha Shukor, and Hasnah Mohamed

Abstract As more learning continues to move online, the implications of extraneous processing for the human memory system, especially within digital learning spaces, calls for instructional approaches that promotes essential processing. This chapter discusses the nature and direct implications of cognitive (over)overload for human working memory, and how to mitigate this in online and technology-mediated learning environments. In a 2-stage, mixed-mode study involving university students in Malaysia, the chapter highlights important elements of pedagogy that instructors can leverage to promote effective technology-aided instruction in the digital, but distraction-loaded learning environments of the twenty-first century.

Keywords Cognitive load · Peer instruction · Extraneous load · Intrinsic load · Essential processing · ConcepTests · Peer discussion

7.1 Introduction

Technology-Enhanced Learning (TEL) can increase the productivity of both students and teachers by reducing the effort, time and cost requirement for tasks; hence, the continued exploration of various emerging media and tools not originally developed for teaching and learning (T&L). Some of these technologies support synchronous or asynchronous educational interactions and multimedia instruction and serve as academic platforms of some sort. Facebook groups, for example, have been extensively employed as informal Learning Management System (LMS). Recently, many previously unknown or overlooked video-conference platforms have suddenly become the only 'classrooms' available and accessible for learning in the wake

B. I. Edwards (✉)
Raffles University, Johor Bahru, Malaysia
e-mail: dr@bosedeedwards.com

Imagineering Institute, Nusajaya, Malaysia

N. Shukor · H. Mohamed
Universiti Teknologi Malaysia, Johor Bahru, Malaysia

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of the COVID-19 pandemic. Zoom Meetings, Google Meet and Hangout, Microsoft Team, and Cisco Webex Meetings are among the foremost of these systems employed during the COVID-19 season (Cha, 2020). Through their support for real-time video interaction, they provided the space for instructor-learner meets, rescuing global education at all levels. Online learning has thus continued to become much more extensive than in previous decades.

In spite of its many advantages, online learning involve cognitive activities whose demands can plague learners with many challenges including distraction (Jafarkarimi et al., 2016), inability to focus, and task switching (Judd, 2014; Rosen et al., 2013). Together, these factors constitute information processing challenges that could result in situations detrimental to learning. This is due to the limited processing capabilities of the human memory system. Cognitive activities place processing demands, measured as mental demand (MD) or Cognitive Load (CL) (Benassi et al., 2014; Paas et al., 2010) on this limited resource. The full amount of CL placed on an individual for a cognitive task comprises of that from the difficulty of the material, known as essential processing or intrinsic load (Sweller et al. 2011), and the demands of unrelated processing, including those generated within the learning environment, by learning technologies, or the pedagogical approach employed by the instructor, which together make up the extraneous load (Fong, 2013).

The interaction between working memory and CL is described by the Cognitive Load Theory (CLT) (Kirschner et al., 2018; Sweller, 2011). Information received through external stimuli (sensory memory) is processed in the working memory, and successfully processed materials are transferred into the long-term memory for permanent storage as schemas. These schemas are automated or organized knowledge units of learned materials (Pankin, 2013). Gilboa and Marlatte (2017) described schemas as 'superordinate knowledge structures that reflect abstracted commonalities across multiple experiences'. These schemas are constantly updated with novel information gained on the associated representation. The main goal of effective instruction is thus, generating a store of prior knowledge from schemas, for direct retrieval and use.

Within highly dynamic, online, technology-mediated learning environments, learners can become susceptible to intensive demands on the working memory from extraneous processing (Hollender et al., 2010). When this demand is in excess of available memory capacity (Edwards et al., 2015), the learning process may be compromised (Mayer & Moreno, 2003). Instruction, including pedagogy, should therefore focus on prioritizing the demands for learning on the distribution of the memory's processing capacity. Effective learning should be guided by the understanding of neuroscience, and should engage techniques that reduce cognitive demands on the memory system, and allows the brain to employ its maximum capacity for essential processing.

Original designs of digital social platforms are for social interactions; hence, the inherent processing demand gives no consideration to essential processing of the type required for effective learning. Learning in such environments can be plagued by poor processing, clogging of working memory, ineffective schema formation, and failed transfer, with resultant inefficient storage and retrieval (Cavanagh & Alvarez, 2005;

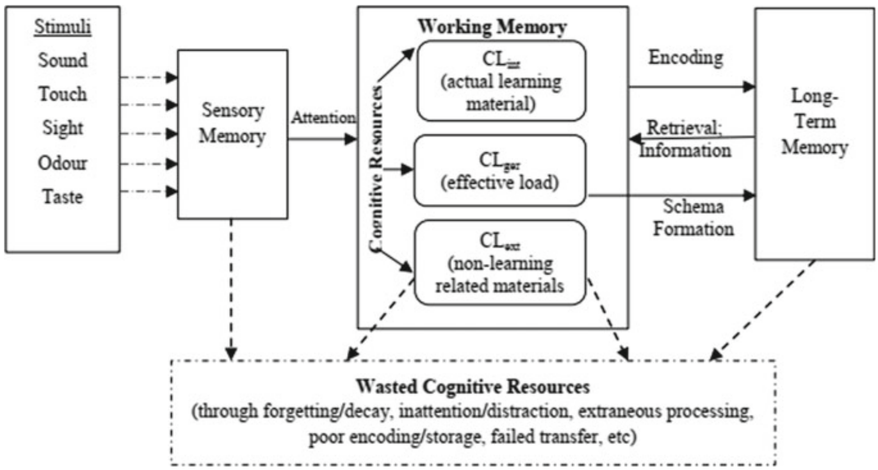

Fig. 7.1 Relationship between CL and information processing in humans (Edwards, 2017)

Liefooghe et al., 2008). The need to minimize demands on the working memory should therefore be central to instructional design (ID) and pedagogy (Mao, 2014). The focus should be on reducing total CL or reducing either extraneous load or of intrinsic demand per time (Bertolo et al., 2014; Chong et al., 2012).

Neither very high nor very low CL is beneficial to learning as low CL can result in boredom or reduced motivation (Leppink & van den Heuvel, 2015). Finding and maintaining a balance of CL high enough to sustain learners' interest and low enough to prevent overload is thus an important focus for instructors. Identifying key sources of extraneous processing within digital learning environments will assist towards creating a CL-appropriate learning environment that promotes learning. Addressing the known factors for promoting CL management is also important in this respect. Cognitive load effects (Mayer & Fiorella, 2016) are factors that describe the principles by which an understanding of CLT can inform instructional design and delivery. Figure 7.1 is a conceptual model of human information processing system; it shows how CL and information processing are related.

7.2 CL Management Through CL Effects in Peer Instruction

Mayer (2009) identifies CL effects including segmenting, pre-training, signaling, and expertise-reversal effects among others. Segmenting focuses on breaking major tasks into sub-tasks (Fraser et al., 2015) to reduce the required processing capacity at each point in the task performance, while pre-training leverages prior learning opportunities for the learner (Li et al., 2013). In both cases, the schema built can be connected to others later (Mayer, 2010). Signaling can employ various procedures aimed at emphasizing essential learning materials such as colour coding, zooming, highlighting, cueing, and pinned posts on digital boards (Edwards, 2017; Johnson et al., 2015). Segmented, rather than integrated information promotes self-paced learning opportunities which helps in preventing both split attention for novices and expertise reversal effect for expert learners (Fraser et al., 2015; Young et al., 2014).

A number of pedagogical approaches are being explored for promoting modern instruction and minimizing the ineffectiveness of lectures. Peer Instruction (PI), popularized in the late 1990s by Eric Mazur (Mazur, 1997), leverages active learning approaches, and focuses on social learning and conceptual understanding. It is based on the four elements: (i) pre-learning, (ii) conceptual understanding through conceptual questions known as ConcepTests, (iii) student voice expressed through classroom voting and (iv) peer discussion for promoting social learning. The instructional process promotes learner reflection and metacognition (Kester et al. 2006). PI has been used extensively across various fields and by many instructors and researchers (Zingaro, 2012; Turpen & Finkelstein, 2010; Arnesen et al., 2013; Vaughan et al., 2011; Roth, 2012). It has also been validated for promoting conceptual and meaningful learning (Simon et al., 2010; Cortright et al., 2005; Crouch & Mazur, 2001), motivation, active learning, problem-solving abilities (Cortright et al., 2005), self-efficacy and improved learning outcomes (Antimirova et al., 2015; Fagen, 2003; Zingaro, 2014).

7.3 Exploring PI for Promoting CL Management

Focusing on Facebook as a representative, informal, digital environment that predates current video-conference platforms, we report on the evaluation of the PI approach to reduce CL during online learning. This situation will become increasingly important as learning gravitates more out of concrete walls. The study focused on identifying the extraneous factors that contribute to increasing CL in many social and digital learning environments, and how PI can be employed for CL management. The findings will enable focused efforts at promoting effective learning and the lessons learnt can be leveraged for addressing similar issues in emerging digital platforms that are becoming the trend. Facebook platform has been used extensively in learning, and several research studies have reported its association with formal learning than any other similar media. Its use as an informal LMS has also been global, but it has also been identified by students as a source of distraction when employed in education even though it has reported the highest level of engagement in terms of number of users than similar media.

7.4 Methodology and Procedure

A two-phase procedure was implemented to address the aims of the study. Phase I focused on (i) what constitutes CL within the FB digital learning environment from learners' point of view, (ii) assessment of the capabilities of the platform to foster or promote CL, and (iii) identifying the various sources of CL, and the relative levels engendered by the various features within the platform. Activities that require cognitive processing are classified as CL. Phase 2 is an experimental mixed-mode study designed to assess the effectiveness of a modified model of PI for reducing CL. A pre-post experimental design was implemented with measures of learning performance and CL ratings as quantitative data. Qualitative data were from focus group, student reflections, peer discussion and class participation. Comparison of regular lecture as the pre- sessions and the PI learning sessions as the post- sessions enabled the evaluation of cause-and-effect relationship between changes in students' CL and learning performance (LP) and the effectiveness of peer instruction to reduce CL.

The Distraction Survey (DiS), a 19-item, 5-category instrument designed to capture information on sources and nature of students' CL while engaging with learning on social media was used for data collection in phase 1. In phase 2, students' CL and learning performance were assessed based on CL rating using the LAWIX and the pre- and post-tests respectively. Facebook was both a learning environment and data collection 'instrument' as students' participation and reflections were captured through Facebook. Reflections provide qualitative information on student perspectives and perceptions (Breyer, 2009; Napier et al., 2011), while participation was based on responses to question items, contribution to class discussions, and votes during the voting sessions. ConcepTests for the voting sessions and performance tests for the pretests and posttests session were developed in consultation with the course instructor based on the weekly content of the course syllabus. Their validity was established through test-retest reliability before they were used to assess LP.

CL was measured using the Learning Activity Workload Index (LAWIX). The instrument was developed to address the challenge of the absence of any established learning-focused workload measures. There were also other challenges which includes the complicated administration procedure of the most popular subjective CL measure, the NASA TLX (Hoonakker et al., 2011). LAWIX is multidimensional, and features a 5-point rating scale for measuring workload based on contributions from four sub-loads including Mental Demand (MD), Time Demand (TD), Difficulty Level (DL), and Affect Level (AL). from lowest load (1) to highest load (5). AL models levels of enjoyment/frustration, engagement or disengagement, interest or disinterest, etc. Hence higher scores represent higher interest/engagement/enjoyment and indicate reduced CL, hence higher ratings in AL indicate lower CL.

Although the study focuses on online learning, observation of related physical learning sessions were carried out to provide important supplementary qualitative information related to the impact of the intervention on classroom engagement, motivation, interaction and learning. Qualitative Instruments thus include an observation scheme and a focus group protocol. The Code for Student Performance Measures or COSPERM (Edwards et al., 2015) was the observation scheme; it employs the time-sample methodology and features learner codes and pedagogical (or instructional context) codes. It is applicable with either single or multiple observers and has a high intra-observer reliability of >0.8. The focus group protocol items were developed in line with LAWIX items. Student reflections, participation data in whole class discussions and data from focus group session were analysed using NVivo Computer-Aided Qualitative Data Analysis Software (CAQDAS) to aid the coding process. Findings were integrated with the quantitative results to provide a comprehensive evaluation of the research objectives.

7.4.1 Study Procedure

Study participants in the first phase of the study were 226 Malaysian university students from various backgrounds; they include undergraduates and postgraduates, as well as international and local (Malaysian) students. Responses confirmed experience of distractions with third party activities identified as the most distracting. In the second phase, a mixed-method study was implemented with a purposeful sample of 12 postgraduate students to investigate the effectiveness of PI for enhancing learning performance and reducing CL. Participants were all Malaysians, but represent various learner groups in terms of employment status, study mode, marital status, parenting status, employment in relation to teaching, etc. Data was collected weekly over a full semester, 42 lecture-hour, of learning. To prevent internal validity threat due to testing, participants were only informed that performance in the learning activities will not count towards course evaluation only during the debriefing session. Two different learning sessions were implemented. The PI Session involved learning and exploration of the elements of PI; pre-class sessions were focused on the topic to be treated in class, CTs presented as quiz were voted for and later discussed. Classroom discussions were conducted on Facebook as the learning environment and post-class learning sessions followed up on issues related to topics learnt in class. Participants were also shared reflections in the Facebook group. This is the intervention session. In non-PI sessions, regular lecture in face-to-face learning sessions were implemented. None of pre-class or post-class discussion, CT or quiz was implemented and there were no personal reflections on learning. Non-participant observation of physical classroom sessions provided data on the effect of pre-class sessions on classroom participation and engagement, compared with the sessions where there were no pre-class learning opportunities.

7.5 Findings and Discussion

Based on the mixed-mode design, both quantitative and qualitative analyses were employed in addressing the research questions. Several hypotheses were generated and tested in the quantitative analysis. Total CL as well as different aspects of the load were tested. Wilcoxon signed-rank test of the difference of CL in the two sessions reveal significantly lower total CL in the PI sessions ($z = -6.03$, $p < 0.05$), indicating that PI is able to reduce total CL. In a similar manner, the four aspects of total CL were tested for both the PI and normal learning sessions. Significantly lower ratings were observed for MD ($z = -5.97$; $p < 0.05$), TD ($z = -4.22$, $p < 0.05$), DL ($z = -5.95$; $p < 0.05$), and AL ($z = -5.48$; $p < 0.05$). The results indicate these PI elements supports the reduction of total CL as well as individual aspects of the total load.

Qualitative data analysis shows that participants reported high CL from distractions and other third-party platform contents (comments, advertisements, etc.). They also reported higher time demand. Qualitative exploration of the textual data using NVivo tools identified important categories and codes related to CL experience and PI elements. The example in Fig. 7.2 shows the mini-model for the quiz element or

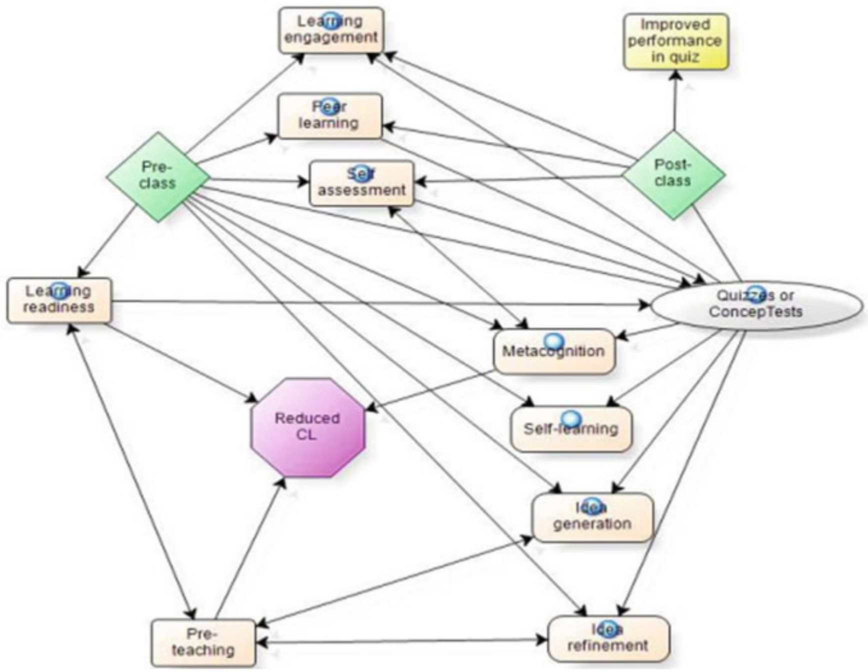

Fig. 7.2 The ConcepTest mini-model

ConcepTest. Similar mini-models were generated for each of voting element, pre-class learning, and peer discussion, which consists of both in-class and post-class discussions. Employing theoretical coding (Papavlasopoulou et al., 2019), concepts and relationships were clarified, and findings aligned with existing theory (Michie & Prestwich, 2010) to clarify and draw conclusions on causal-relationships (Urquhart, 2012). The initial or substantive model was generated from the sum of all mini-models. Findings were correlated with existing models to evaluate links between concepts in the theoretical coding stage. It shows material difficulty is correlated with MD (Paxion et al., 2014) and intrinsic load (Merriënboer & Ayres, 2005; Sweller et al., 2011), while MD is correlated with attention (Berka et al., 2007; Manna et al., 2010) and distractions (Bailey & Iqbal, 2008).

The substantive model thus shows how constructs are linked in the reduction of CL. Further review in line with the study objectives and findings was used to generate the final conceptual model that highlighted how intrinsic load is reduced based on sequencing of information presentation (i.e. presentation of materials in simple-to-complex manner to simplify task-complexity). The sequencing process is essentially instructional scaffolding. Most of the CL effects are similar to scaffolds since they are meant to assist the learner in learning (Fraser et al., 2015) although the pre-training and segmenting effects are more focused on scaffolding than others.

The use of conceptual question items and pre-class contact with learning material are some of the ways pre-training and segmenting were done. Vygotsky's theory and the ZPD underscores the role of discourse, dialogue and other types of techniques that foster social learning as scaffolds. Collaboration, an essential part of the PI process supports CL-sharing (Kirschner et al., 2009), in addition to increasing learners' interest and engagement (Fraser et al., 2015). Instructional strategies that foster group cohesion, problem-solving and active learning have also been known to be highly effective in addressing CL management (Brill & Hodges, 2011). Pedagogies that employ peer-review strategies were noted as particularly effective in this respect. When they are used with technology, they can combine collaborative, active and social learning approaches with peer learning, peer instruction, and teacher-supported peer assessment (Zhao, 2014) to reduce CL.

7.6 Conclusion

Quantitative analysis of test scores and CL ratings were combined with analysis of qualitative data to identify the factors of PI responsible for promoting CL reduction. Qualitative data analysis revealed relationships among the categories identified in the coding process. The development of the modified model of peer instruction for reducing cognitive load during learning in social environments has peer discussion as a central factor that links up three other peer instruction elements: student voice (voting), conceptual learning (ConcepTests) and pre-class learning. PI engaged the affordances of digital platforms to support pre-training or segmenting, metacognition, conceptual learning, peer learning, social and collaborative learning and other student-focused and active learning strategies. This results in the lowering of students' cognitive load. The model thus features a two-part framework with a pre-class and a post-class session of peer instruction.

As online learning becomes more extensive and ubiquitous, and as future learning spaces extends into various types of environment with high levels of cognitive processing demands, instructors and instructional designers can take advantage of this instructional model to promote CL management, thereby supporting students' experience of effective learning.

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