CJLT RCAT
Canadian Journal of Learning and Technology
La Revue canadienne de l'apprentissage et de la technologie

Volume 48 (4) Special Issue 2022

Editorial / Éditorial

Professor Mohamed Ally

Professor Weiyuan Zhang

This special issue of the Canadian Journal of Learning Technology contains articles presented at the *Rethinking Online Education in the Knowledge Society with Emerging Technology Symposium* jointly hosted by Beijing Normal University, Athabasca University, and Chongqing Open University in November 2021. The symposium was organized by the Chongqing Open University, China.

The first article, ***Theoretical Development of Connectivism through Innovative Application in China****,* on connectivism in MOOCs by Li Chen and Yaqian Xu from Beijing Normal University sets the stage to discuss how education can be innovated to reach massive audiences to help reach the United Nations' goal of Education for All and the Sustainable Development Goal 4 "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all." The MOOC research team at the Distance Education Research Centre at Beijing Normal University designed and developed the first massive open online course in China, adapting a connectivist (cMOOC) approach. Using the data collected from six offerings of the cMOOC over three years, the big data paradigm was used for data analysis including complex network analysis, content analysis, text mining, behaviour sequence analysis, epistemic network analysis, and statistical and econometric models.

Artificial Intelligence in the Fourth Industrial Revolution to Educate for Sustainable Development by Mohamed Ally and Kirk Perris is timely because of the increasing interest in the use of fourth industrial revolution technologies, such as artificial intelligence, to help achieve the Sustainable Development Goals. Also, there is rapid development for using fourth industrial revolution technologies in society. This article addresses how artificial intelligence can be used for education and sustainable development.

Jingxin Jiang and Fei Victor Lim write ***Designing Knowledge Dissemination in a Digital Era – Analysing TED Talk's Multimodal Orchestration*** which examines how scientific knowledge is disseminated in one of the most widespread academic genres, TED Talks, and shares discoursal similarities with other academic genres such as online lectures. The study adopted a systemic functional multimodal discourse analysis approach to explore how a presenter used speech, images, and gestures to disseminate knowledge.

Tammy Soanes-White's ***Defining and Exploring Broadband Connections and Education Solutions in Canada's North*** addresses broadband connections in northern Canada. It analyzes the impacts that broadband capacity and Internet access have on remote education by examining geographic information system data, which offers a framework that connects spatial and temporal data to analyse accessibility of remote education.

Analysis of the Status and Influencing Factors of Online Learning by Jiaju He, Hong Zhao, and Fei Jiang describes a study that used a questionnaire survey with primary and high school students. The survey was conducted from four aspects: demographics, online learning preparation, online learning situation, and online learning experience. This study thoroughly investigates the status and problems of students' online learning and analyses the characteristics of students' online learning and the differences among the grades.

The article ***It's Happy Hour Somewhere: Videoconferencing Guidelines for Traversing Time and Space*** by Aga Palalas, Rebecca Heiser, and Ashley Gollert claims that one benefit of videoconferencing is that it can address time and distance boundaries. With this advantage also comes a challenge - the pressures of time and time not being used purposefully often negatively impact the online learning experience and the digital wellness of its participants. Drawing on a systematic review of the relevant literature of the last decade, temporal guidelines have been distilled to promote the design of videoconferencing-based learning that is conducive to successful learning while maintaining digital well-being.

Jeanne Kim examines ***The Interconnectivity of Heutagogy and Education 4.0 in Higher Online Education***. Industry 4.0 advancements in technology are creating a dynamic and fast-changing world that affects how we live and work. Heutagogy, or self-determined learning, is an approach that promotes critical thinking, social-emotional skills, and life-long learning. Educators need to rethink existing teaching approaches to better prepare learners for future careers that Industry 4.0 will create. Kim makes recommendations on principles of heutagogy as an effective teaching and learning approach to meet the skills and needs necessary for Education 4.0.

In ***Dynamic Evolution Analysis of Social Network in cMOOC Based on RSiena Model,*** Yaqian Xu and Junlei Du provide information on the first connectivist massive open and online course (cMOOC) in China, "Internet plus Education: Dialogue between Theory and Practice" as the research object, using the dynamic analysis method of social networks which is based on stochastic actor-oriented models, to reveal the influence of the individual attributes and network structural attributes on the dynamic evolution of social networks in a cMOOC.

Cognification in Learning, Teaching, and Training: A Discussion highlights how emerging trends in cognification could disrupt online education. Vivekanandan Kumar, Mohamed Ally, Avgoustos Tsinakos, and Helmi Norman team up to address cognification techniques that design complex data analytic models which allow natural intelligence to engage artificial smartness in ways that can enhance the learning experience. Cognification is defined as the approach to make something increasingly, ethically, and regulatably smarter.

Teaching Architectural Technology Knowledge Using Virtual Reality Technology by Yi Lu describes how to teach architectural technology knowledge using virtual reality. The traditional pedagogical method adopts a series of two-dimensional drawings to explain three-dimensional objects. While architectural design education has begun exploring integrating virtual reality tools in the classroom, especially in the early design stage, this article explores if virtual reality can assist in teaching architectural technology knowledge.

In ***Removing Learning Barriers in Self-paced Online STEM Education***, Hongxin Yan, Fuhua Lin, and Kinshuk address how to remove barriers in online STEM education which is important because of increasing use of emerging technologies. They note that self-paced online learning provides great flexibility for learning, yet it brings some inherent learning barriers because of the nature of this educational paradigm. The authors propose some corresponding strategies to address these barriers in order to create a more supportive self-paced online learning environment.

The articles are written by experts and emerging scholars in the field of educational technology making this special issue relevant to readers at various levels in educational technology.

Guest Editors

Mohamed Ally is Professor of Online and Distance Education at Athabasca University, Canada. His current areas of research include education in the fourth industrial revolution, mobile learning, online learning, distance education and use of emerging learning technologies in education. He is currently serving on three ISO committees to set international standards. Email: mohameda@athabascau.ca

Weiyuan Zhang is Professor in the Faculty of Education at Beijing Normal University in China and specially invited expert at Chongqing Open University/Chongqing Technology and Business College. He was the former Chief Researcher, head of the Centre for Research in Continuing Education and Lifelong Learning, Head of the Centre for Cyber Learning, School of Professional and Continuing Education at the University of Hong Kong, China. Email: zhangweiyuan@bnu.edu.cn

CJLT RCAT
Canadian Journal of Learning and Technology
La Revue canadienne de l'apprentissage et de la technologie

Volume 48 (4) Special Issue 2022

Theoretical Development of Connectivism through Innovative Application in China

Développement théorique du connectivisme à travers une application innovante en Chine

***Li Chen**, Beijing Normal University, China*
***Yaqian Xu**, Beijing Normal University, China*

Abstract

Connectivism, a learning theory that reveals a new learning in the Internet environment, has become a popular academic topic at the forefront of online learning. The MOOC Research Team at the Distance Education Research Centre at Beijing Normal University designed and developed the first massive open online course in China, adapting a connectivist (cMOOC) approach. Using the data collected from six offerings of the cMOOC over 3 years, the big data paradigm was used for data analysis including complex network analysis, content analysis, text mining, behaviour sequence analysis, epistemic network analysis, and statistical and econometric models. This paper summarizes the findings of the patterns of connectivist learning, including a) the basic characteristics and evolutional patterns of complex networks, b) the characteristics and modes of knowledge production, c) the patterns of instructional interactions, and d) the relationships between "pipe" (connection) and content and between facilitators and learners. It is expected that the outcome of this study could make contributions to understanding the changes of online learning in depth and further promote the theoretical development and practical application of a connectivist approach.

Keywords: Connectivism; Innovative application; Online learning; Technology and learning

Résumé

En tant que théorie d'apprentissage qui révèle un nouvel apprentissage dans l'environnement internet, le connectivisme est devenu un sujet académique populaire à la pointe de l'apprentissage en ligne. L'équipe de recherche MOOC du Centre de Recherche sur l'Enseignement à Distance de l'Université Normale de Pékin a conçu et développé le premier cours en ligne ouvert et massif, adaptant une approche connectiviste (cMOOC) en Chine. À partir des données recueillies dans le cadre de six offres du cMOOC sur une période de trois ans, le paradigme du big data a été utilisé pour l'analyse des données, y compris l'analyse de réseaux complexes, l'analyse de contenu, l'exploration de textes, l'analyse de séquences de comportements, l'analyse de réseaux épistémiques et les modèles statistiques et économétriques. Cet article résume les résultats des modèles d'apprentissage connectiviste, incluant a) les caractéristiques de base et les modèles d'évolution des réseaux complexes, b) les caractéristiques et les modes de production de connaissances, c) les modèles d'interactions pédagogiques, et d) les relations entre le tuyau d'information et le contenu et entre les facilitateurs et les apprenants. On s'attend à ce que les résultats de cette étude puissent contribuer à une compréhension approfondie des changements de l'apprentissage en ligne et promouvoir davantage le développement théorique et l'application pratique d'une approche connectiviste.

Mots-clés : Connectivisme ; application innovante ; apprentissage en ligne ; technologie et apprentissage

Introduction

In 2005, facing the challenge to human learning from the overload of available knowledge in the Internet era, George Siemens and Stephen Downes proposed connectivist theory, offering a new perspective of interpreting learning and knowledge generation. The connectivist theory argues that knowledge is a dynamic, invisible, and generative network phenomenon (Downes, 2005). According to this theory, possession and grasp of knowledge is not the goal of learning; instead, learning is a process of continuously building connections and developing networks (Siemens, 2005). Together, the interactions among three levels of networks (the individual level, group level, and collective level) and among three types of networks (cognitive neural networks, concept networks, and social networks) have enhanced learning development and knowledge innovation. Once proposed, connectivist theory drew much attention from researchers and practitioners in China and abroad. As of November 2021, the paper that first explained the connectivist theory, "Connectivism: A Learning Theory for the Digital Age," had been cited 4,687 times. Since 2010, research on connectivism has grown in waves. In 2011, The *International Review of Research in Open & Distance Learning* journal published a special issue entitled "Connectivism: Design and Delivery of Social Networked Learning" to encourage researchers across the world to engage in explorations of connectivism. In terms of practice, beginning in 2008, the team of George Siemens and Stephen Downes developed a series of online courses guided by connectivism, providing rich experiences for the design and development of cMOOCs later in China and abroad.

In October 2018, the Distance Education Research Centre MOOC Research Team designed and developed the first cMOOC in China, named "Internet plus Education: Dialogue between Theory and Practice." As of August 2021, six offerings of the cMOOC were delivered, which promoted the localization of connectivism in China and provided abundant data to support further exploration of the patterns of connectivist learning. Based on the big data paradigm, the data collected from users on the e-learning platform and through questionnaire survey and interview was analyzed including complex network analysis, content analysis, text mining, behaviour sequence analysis, epistemic network analysis, and statistical and econometric models. The outcomes of the research were published in several Chinese academic journals relating to four aspects: the patterns of complex networks, patterns of knowledge generation, patterns of instructional interactions, and two important relationships between pipe and content and between facilitators and learners in connectivist learning. It is hoped that, by detailing these findings over the past 3 years, this paper will provide theoretical support to practitioners in online learning and prompt researchers to rethink the connectivist theory, and together with these stakeholders to promote the application and development of connectivism.

Methodology

Participants

Over the past 3 years, the MOOC research team designed and developed the cMOOC, *Internet plus Education: Dialogue between Theory and Practice*, and carried out a series of studies based on six offerings of the cMOOC. The number of participants in each of the six offerings are summarized in Table 1.

Table 1 shows that a total of 5,426 people participated in the six cMOOC courses. Among them, 36.07% were male and 63.93% were female. The age ranged between 19 and 65 years with an average age of 31 years, and the students attended from 34 provincial-level administrative regions in China.

It was also found that the majority of learners were willing to share their ideas and experiences, including frontline teachers (about 36.09%), educational managers (about 8.61%), industry practitioners (about 11.60%), and students (about 39.22%).

Table 1

Number of the Participants in Each cMOOC Course Offering

Round	Students
cMOOC1.0	602
cMOOC2.0	1,445
cMOOC3.0	876
cMOOC4.0	1,660
cMOOC5.0	595
cMOOC6.0	248
Total	5,426

Curriculum Design and Arrangement

The *Internet plus Education: Dialogue between Theory and Practice* cMOOC is an open, distributed, learner-defined, generative community course. It is the first cMOOC developed in

China using connectivism after a series of cMOOCs opened to the public by George Siemens and Stephen Downes. In this cMOOC there were five complex topics in the field of "Internet plus education," which included the philosophy of the Internet plus education, the fusion of online and offline learning spaces, co-construction and sharing of social education resources, consumption-driven education supply-side reform, and the use of an accurate and efficient education management model. Learners with different expertise and experiences have made active contributions in the courses, carried out multi-modal interaction and discussion around complex practical problems, promoted complex problem-solving and knowledge creation through the aggregation of collective wisdom, and built an open learning community in the field of Internet education. On October 17, 2018, the first cMOOC was offered, and by August 2021, the course had run six times. Each cMOOC ran for about 12 weeks, with the course cycle upgrading, the course content, activities, platform, and operation mode continued to evolve iteratively. The basic information collected from the six cMOOCs is shown in Table 2.

Table 2

Basic Information of the Six cMOOC Course Offerings

	Course dates	Orientation and characteristics	Content generation
cMOOC1.0	2018.10.17 - 2019.01.05	Case analysis and theoretical discussion	14 online or offline seminars, 66 daily posts, 10,568 interactive behaviours, 310 blogs, 431 cases and resources
cMOOC2.0	2019.03.12 - 2019.06.11	Explore patterns, share tools, and create solutions	10 online or offline seminars, 5 tool-sharing activities, 23 weekly posts, 54 forum topics, 1,042 articles
cMOOC3.0	2019.10.14 - 2020.01.05	Emphasize connectivity and collaboration to solve real problems	5 online seminars, 18 theme learning videos (4h 23min), 12 weekly posts, 54 forum topics, 13 collaborative groups
cMOOC4.0	2020.03.16 - 2020.06.07	Based on the epidemic practice, focus on real problems	7 online seminars, 12 weekly posts, 46 forum topics, 12 collaborative groups, 1006 articles, 3514 comments
cMOOC5.0	2020.10.12 - 2021.01.03	Optimize activity design, enrich learning support, and emphasize collaboration	9 online seminars, 11 weekly posts, 61 forum topics, 12 collaborative groups, 393 articles, 828 comments.
cMOOC6.0	2021.06.01 - 2021.08.22	Simplify content and focus on practical issues	3 online seminars, 11 weekly posts, 11 forum topics, 5 collaborative groups, 205 articles, 563 comments

Data Analysis

In the past 3 years, based on the practice of six cMOOC offerings, the research team collected data from the e-learning platform and from questionnaires and interviews, followed by a data-intensive research paradigm. The team carried out a systematic study using a variety of data analysis methods, such as complex network analysis, content analysis, text mining (like Word2vec and the Latent Dirichlet Allocation), lag sequence analysis, epistemic network analysis, and statistical and econometric models. A series of research findings were produced and published in Chinese academic journals related to four aspects, including patterns of complex networks, patterns of knowledge generation, patterns of instructional interactions, and the two important relationships between pipe and content and between facilitators and learners in connectivist learning.

Results

Patterns of Complex Networks in Connectivist Learning

Connectivist learning depends on an open and connective network environment. The formation and development of networks are essential characteristics of learning (Siemens, 2005), with each learner situated in a complex learning network. Since the beginning of 2000, research on social networks has grown exponentially (Porter & Woo, 2015). An increasing amount of research has applied complex network analysis to explore patterns in connectivist learning, with a major focus on the structures and characteristics of social networks. The social network is usually defined as a complex network structure made up of individuals and their social relations. The complexity of social networks is mainly reflected in the diverse characteristics of network connections, the dynamic evolution of network structures, and the influences that networks exert on each other (Huang & Tan, 2017). The research team attempted to reveal the patterns of complex networks in connectivist learning from two perspectives: the basic structural characteristics and the evolutional patterns.

Basic Characteristics of Complex Networks in Connectivist Learning

The static overall, local, and individual network indicators were employed to reveal complex networks' basic structural characteristics in connectivist learning: overall indicators include the size, topology, density, diameter, average clustering coefficient, and average path length. Existing research typically uses the overall indicators to measure social networks' cohesion and degree distribution (Tirado et al., 2017; Zhou, 2010). Local analysis indicators are usually employed to analyze the structures of groups in networks (Skrypnyk et al., 2014), including the largest connected region, elements, factions, and block models. Individual indicators are usually used for examining nodes' positions and roles in network, including such indicators as degree, closeness centrality, betweenness centrality, eigenvector centrality, k-shell, structural holes, and middleman. As show in Table 3, different individual indicators can measure individuals' status and roles in networks from different perspectives (Xu & Du, 2021). Usually, researchers select two or three indicators to measure individuals' behavioural tendencies in networks (Tawfik et al., 2017).

Table 3

The Evaluation Framework of Individual Status in Social Networks in cMOOC

Indicators	Its representational significance in learning
In-degree	One's popularity during interaction
Out-degree	One's initiative during interaction
Betweenness centrality	One's power to control information flow
Closeness centrality	One's closeness to other learners
Eigenvector centrality	One's closeness to other important learners
K-shell	One's power to information spreading

Note. From "What participation types of learners are there in connectivist learning: an analysis of a cMOOC from the dual perspectives of social network and concept network characteristics," by Xu and Du, 2021, *Interactive Learning Environments*, p.3. (https://doi.org/10.1080/10494820.2021.2007137). Copyright 2021 by Informa UK Limited, trading as Taylor & Francis Group.

There were two findings on the basic characteristics of complex networks in the study. First, there were four characteristics of social networks in connectivist learning: self-organized, multi-cored, modularized, and small-world effect. By analysing the clustering subgroups in the cMOOC1.0 social network and calculating indicators of network status by Ucinet (a tool for social network analysis), it was found that learners self-organized into multiple subgroups, the social network demonstrated a multi-centre characteristic, and some core learners whose status was equal to or higher than that of facilitators had emerged (Guo et al., 2020; H. M. Wang & Chen, 2019). Using the cMOOC2.0 data to retest the characteristic of self-organization, it was found that after deleting the facilitators' nodes, the modularity index of the social network increased from 0.202 to 0.252, indicating that in the absence of facilitators, learners will create their own communities, although groups still exist by self-organization (Yu et al., 2020). Several analyses also indicate that the diameter of the social network formed under the cMOOC is less than 6, the average path length is approximately 2.5, and the average clustering coefficient is approximately 0.32. These values show that there is a small-world effect and a compact structure in the social network; because of this, information propagation in it is fast (Guo et al., 2020; Xu, 2020; Yang et al., 2020).

Second, using the cMOOC2.0 data, the research team further tested the influences of special nodes on the structure of the collective network. Comparing the network structure parameters before and after the bridge learners (acting as a mediator to facilitate connections between other learners) were deleted, it was found that after deleting bridge learners, the network's average degree, density, average clustering coefficient, and modularity index all decreased significantly, while the average path length increased. The average value of the nodes' degrees in the network saw a significant decrease as well. These findings indicate that the bridge learners can influence the others' number of connections and increase the level of modularity in the network (Yu et al., 2020).

Evolutional Pattern of Complex Networks in Connectivist Learning

By converting the dynamic network into several static networks at certain time intervals, calculating and analysing the changes of indicators over time, and using descriptive statistics analysis, the evolutional pattern of complex networks in connectivist learning can be revealed. The time intervals, based on the week, learning topic, and important activity nodes, were chosen according to the purpose of different studies. The research team gave attention to the evolution of the whole network structure and the tendency of individual connections. The evolutional analysis of the whole network is supported by indicators such as the network density, average path length, average clustering coefficient, and average degree, while the degree correlation was used to measure individuals' tendency to develop and maintain connections.

It was found that there was the phenomenon of class differentiation, or "the rich getting richer" in connectivist social networks, based on our analysis of the evolution of the degree distribution in the cMOOC2.0 network. This shows that as the course progresses, some learners become stable active learners at the centre of the network and become the ones with whom most learners would like to actively interact. According to the correlation analysis of learners' interactions (behaviours of sending and receiving messages) during a given week and their degrees (number of connected leaners) in the previous week, it appears that the frequency of learner's interaction behaviour has a moderately strong correlation with their degrees in the previous week. In other words, the greater the degrees of the learners, the more active they will be in later connections and the more likely it is that they will be connected. This finding indirectly suggests that learners tend to choose others with greater degrees (leaners who make more connections) when building connections (Xiong, 2020).

Meanwhile, it was also found that the structures of connectivist social networks were increasingly compact, and the speed of information propagation was accelerating. The learning topic was used to set time intervals and analyze the evolutionary trend of the cMOOC1.0 social network parameters over time. According to the results, although the number of participants differed, the networks' average degree (from 9.797 to 11.243), density (from 0.0811 to 0.113), and average clustering coefficient (from 0.281 to 0.448) showed growing trends, while the network diameter (from 8 to 5) and average path length (from 2.794 to 2.399) gradually decreased. In other words, as the course progresses, learners slowly adapt to this type of learning and gain the ability to develop more connections with peers. In comparison with the social networks formed under Weibo (a social platform in China, of which the average path length is 3.09 and the average clustering coefficient is 0.21) and the Renren Web (another social platform in China, of which the average path length is 3.48 and the average clustering coefficient is 0.20), social interactions between cMOOC learners are closer and more frequent, and the speed of information propagation gradually increases (Xu, 2020).

Patterns of Knowledge Generation in Connectivist Learning

In his book *Knowing Knowledge*, George Siemens (2006, p. 17) divided knowledge into hard knowledge and soft knowledge based on the speed of change. In the Internet environment, the amount of information is dramatically growing, the information decay cycle is becoming shorter, the pace of information renewal is accelerating, and there is increasingly more soft knowledge. Soft knowledge includes large quantities of instant and practical experiences that are absent from books or hard knowledge. As a new type of learning, connectivist learning is exactly oriented toward soft knowledge. It not only explains the new learning phenomena on the Internet, but also reveals the new connotation of networked knowledge and new ways of knowledge generation.

New Characteristics of Knowledge in Connectivist Learning

Siemens and Downes offered a series of opinions on the new connotation and characteristics of knowledge in connectivist learning, including the following: a) Knowledge is a network phenomenon (Downes, 2005). The organizational form of knowledge uses dynamic networks, no matter whether the knowledge exists in individuals' brains or in society (Siemens, 2006, p. 2); b) Knowledge in networks is dynamic (or mobile), invisible, and generative; and c) Contents, contexts, and pipes formulate the meaning of knowledge. Contents start the circulation of knowledge, contexts make knowledge meaningful, and pipes make it connected, transmitted, and accessible (Siemens, 2006, p. 122). These comments highlight that knowledge in connectivist learning has new characteristics, and there is a need to develop an in-depth understanding of new knowledge based on data and practical context. On one hand, based on experience delivering the cMOOCs, the research team strived to enrich the understanding of the new knowledge in connectivist learning and developed a theoretical model of networked knowledge. On the other hand, diverse methods were used to reveal the characteristics of cMOOC knowledge. For example, the word2vec algorithm was used to output word vectors (Li et al., 2020), and the latent Dirichlet allocation method was employed to mine the topics generated in the cMOOCs (Xu & Du, 2021).

It was found that knowledge in connectivist learning demonstrates new characteristics in terms of, for example, the connotation, structure, producers, vitality, forms of media, and production and transmission processes (Chen et al., 2019; Wang & Chen, 2020). The connotation of knowledge is enriched, including dynamic and generative knowledge, empirical and practical knowledge, inter-disciplinary and fractional knowledge, and selective and individualized knowledge. Knowledge is time- and context-sensitive, only meaningful in certain contexts; existing in networks formed by individuals, organizations, and machines, and generated, developed, and filtered with fragmented and distributed forms. Knowledge producers are more diversified than ever, and learners with different identities, experiences, and backgrounds can all participate in knowledge production. Problem-driven strategies and collective intelligence aggregation have become the main mechanisms for knowledge innovation. Knowledge evaluation is usually based on whether it can meet individual needs, and the requirements for consensus and normalization have been reduced. The media that carry knowledge is diverse, such as videos, pictures, sounds, texts, and computer programs. The Internet has simplified the processes of knowledge generation and transmission, and a large amount of knowledge can be spread and shared via the Internet the moment it is created.

Supported by the course data, the research team further tested certain characteristics of knowledge based on empirical evidence. Under the same topic, the word2vec algorithm was used to extract words from the cMOOCs and journals. The comparison indicated that knowledge generated from cMOOCs was dynamic, holding a practical orientation and coming from multiple perspectives, while traditional knowledge represented by periodical articles was characterized by having an academic perspective, holding a theoretical orientation, and being systematic in nature (Li et al., 2020).

New Modes of Knowledge Generation in Connectivist Learning

In the view of connectivist learning, knowledge exists in diverse viewpoints, and knowledge generation should be due to collective efforts (Siemens, 2005). Downes defined it as organic growth knowledge production (Downes, 2012, p. 490). Although some researchers compare it to the mining mode and the constructive mode of knowledge generation, they have not uncovered the intrinsic patterns and evolutionary trends of knowledge generation based on practice. The research team attempted to use ecological evolution analysis and content analysis to explore the characteristics of knowledge generation in cMOOC. In the ecological evolution analysis, cMOOC was viewed as an organism of knowledge generation. There were knowledge adoption, knowledge evolution, and knowledge demise treated as variables in the knowledge generation system, and the quantity of knowledge produced was a function of time. Based on the above settings, a quantitative model of knowledge generation (Lu & Chen, 2019) was built and the content analysis was conducted to code topics and roles of knowledge generation in cMOOC.

In this study, knowledge generation in connectivist learning followed a bottom-up pattern of reiteration and collective intelligence aggregation. The quantified model of knowledge production was proposed, and as the cMOOC1.0 progressed, the proportion of self-generated knowledge by learners and the proportion of knowledge demise both increased, while the proportion of external knowledge input decreased. This shows that cMOOC knowledge is generated via internal reiteration. External information and resources are important at the beginning of knowledge production, and the processing, integration, and recreation of such knowledge by cMOOC learners is crucial to knowledge innovation (Lu & Chen, 2019). The content analysis was used to code topics generated during cMOOC2.0. By treating topics as nodes and building links based on whether different topics involved the same participant, the topic generation network was constructed and visualized. It was found that many similar concepts slowly aggregated in the dynamic generation process, reflecting a bottom-up mode of collective wisdom rather than a knowledge classification system decided by experts' experience (Yang et al., 2020).

Meanwhile, content analysis was used during knowledge generation to divide individuals' roles into three types: opinion producers (who usually identify phenomena or use verbal expressions without clear structures), process promoters (who enhance knowledge generation, like raising questions or expressing viewpoints), and miners of the knowledge (who often reflect or integrate viewpoints). The opinion producers do not necessarily promote the process of knowledge evolution; however, the participation and contribution of other roles are important forces to drive knowledge generation. Furthermore, by analysing 100 knowledge-generation discussions (half of them were responded to by facilitators), it was found that appropriate response from facilitators, like giving timely reminders, raising topics, guiding and focusing attention, can enhance the efficiency of knowledge production and make viewpoints more structured and logical. However, over-responding may stifle or even completely stop the knowledge-generation process (Lu & Chen, 2019).

Patterns of Instructional Interactions in Connectivist Learning

Interactions are the core of connectivist learning (Wang et al., 2014). Although Siemens and Downes did not specifically elaborate on it, the viewpoints on knowledge, learning, courses, teachers, students, and learning environment of connectivism all reflect the fundamental role that interactions play. That is, knowledge in connectivist learning comes from interactions between various entities (Downes, 2012, p. 68), and the formation of networks depends on the proceedings of interactions. Course content is generated through interactions, and the construction of individual learning environments is in effect creating a space for interactions. Wang et al. (2014) proposed the framework for interaction and cognitive engagement in connectivist learning contexts (referred to as "CIE model"), which divides instructional interactions in connectivist learning into operation interactions, way-finding interactions, sense-making interactions, and innovation interactions. The CIE model has become an important theory that provides powerful interpretation and guidance to the research on the patterns of instructional interactions in connectivist learning. Based on the CIE model, the research team further explored the interrelationships between the four levels of interactions, as well as the relationship between the interaction level and the network status.

Interrelationships Between Four Levels of Instructional Interactions in Connectivist Learning

According to the CIE model, interaction in connectivist learning is a networked process with recursion rather than being a linear one. Specifically, each level of interaction affects the other levels. Lower levels of interaction are the foundations and supports of the higher ones, while interactions at higher levels extend the need for lower levels (Wang et al., 2014). The research team used content analysis to code the interaction levels and used lag sequential analysis to test and interpret the interplays between different levels.

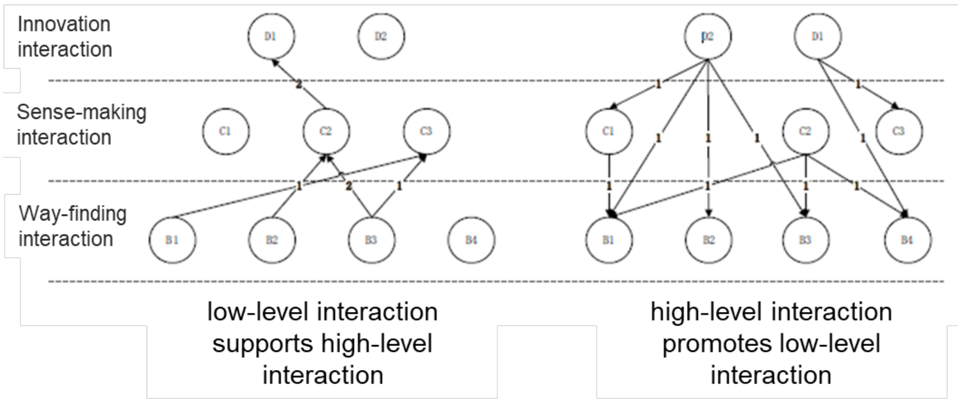
This study indicates that interactions at higher levels of the CIE model do not necessarily depend on interactions at lower levels, but interactions at higher levels can prompt the occurrence of interactions at lower levels (Huang et al., 2020). The data used included, 1,004 interactive texts generated through the forums and blogs in cMOOC2.0. Each topic or blog, along with the replies and comments to it, was treated as a separate analysis unit. The texts contained in each unit were coded according to time series to reflect their level of interactions. Following the above procedures, 176 interaction series were created, and lag sequential analysis was then employed to explore the time-series transfer modes of different levels (Figure 1).

Figure 1 shows that the occurrence of interactions at higher levels does not necessarily depend on interactions at lower levels, although there exists a support relationship in some low-to-high interactions. For example, active direct wayfinding (B2) and helping others by wayfinding (B3) enhance discussions and consultations (C2), further supporting integration for knowledge production (D1). However, some high-level interactions, such as learning products innovation (D2), do not need the support of other lower levels of interaction for their occurrence.

It also can be seen from Figure 1 that higher levels of interactions extend the need for lower levels, characterised by level-jumping, mutual complementation, and weak recursion. Specifically, level-jumping is reflected in the fact that innovation interactions directly extend to wayfinding interactions, and the mutual complementation is reflected in the fact that the paths of two types of innovation interactions interacting with lower interactions are completely different. Besides, the weak recursion is reflected in the fact that the mediating effect of sense-making interactions is reduced by the path through innovation interactions directly extending to wayfinding interactions.

Figure 1

Path Analysis of Different Levels of Instructional Interactions



Note. From "Instructional interactions in connectivist learning," by Huang, Chen, Tian, and Wang, 2020, *Distance Education in China,* (09), p.59. (https://doi.org/10.13541/j.cnki.chinade.2020.09.007). Copyright 1994-2020 by China Academic Journal Electronic Publishing House.

Relationship Between Level of Interaction and Individual's Network Status in Connectivist Learning

Based on the connectivist learning viewpoint, learners build connections with people or content through interactions, and thus develop their networks (Wang et al., 2014). The research team used the CIE model to further explore the relationship between individuals' level of interaction and their status in networks. The level of interactions was coded through content analysis. As well, individuals' status in the networks was evaluated by social network analysis. A set of indicators, including the in-degree, out-degree, betweenness centrality, eigenvector centrality, closeness centrality, and k-shell, were used to evaluate individuals' importance in social networks. Further, special roles in the network, such as opinion leader and middleman, were identified by structural holes and the middleman index (Xu, 2020).

The study found that learners who have a higher status and stronger influence in social networks usually have higher levels of interactions. Using the core–periphery matrix and degree centrality to divide participants in the cMOOC1.0 social network into 21 core connecters, 14 peripheral connectors, and 14 marginal learners, it was shown that core connectors had a higher frequency of higher-level interactions, followed by peripheral connectors (H. M. Wang & Chen, 2019). Using 10,598 pieces of interactive data generated by cMOOC1.0, the correlation of the individuals' network status with their average level of interaction and the highest level of interaction was further examined. The findings indicated that individuals' network status had a positive correlation with the level of interaction, and that the eigenvector centrality and out-degree can better represent the interaction level. In other words, the more participants that one connected with, and the closer one's relationship to high-impact participants, the higher one's level of interaction (Xu, 2020).

In addition, it was also found that special roles with stronger influences in social networks, such as structural hole (identifying the opinion leader in the network) and middleman (identifying the special role of bridging different individuals or groups), usually had a higher level of interactions. Following the filtering rules of "effective size >25, class degree >0.29, and constraint <0.25," seven structural holes that had stronger influences in cMOOC1.0 were selected. Meanwhile, the honest broker index was used to select middlemen. The results indicate that the average interaction level and the highest interaction level of structural holes and middlemen, who showed stronger influences, were usually higher than those of others (Xu, 2020).

Two Important Relationships in Connectivist Learning

Connectivism emphasizes the important role that connection plays in learning and mentions that "the pipe is more important than the content within the pipe" (Siemens, 2005, para. 33). It has subverted the traditional opinions on teaching which view the content as the most important element in learning. The research team attempted to explore the relationship between connections and content in connectivist learning. Connectivism emphasizes that facilitators are important nodes in networks and their role is to influence and shape the networks, which subverts the traditional view of teachers as an authority status. This study attempted to reveal the relationship between facilitators and learners based on empirical evidence.

The Relationship Between Connections and Contents in Connectivist Learning

George Siemens (2005) pointed out the importance of the pipe in connectivist learning especially at a time when knowledge is continuously growing, and knowledge is needed but is often not understood. Knowing the sources of valuable information has become a critical skill; in other words, knowing where knowledge is and understanding the methods to obtain it is more important to learners than the knowledge they acquire. Because of this, connectivism emphasizes the importance of building connections. Viewing knowledge innovation as the goal of connectivist learning, social network analysis and descriptive statistics were used to quantify the characteristics of pipes, the keyword extraction algorithms (such as TextRank, and term frequency–inverse document frequency), and descriptive statistics to determine and analyze the contents of the pipes. Correlation analysis was used to compare the importance of pipes and contents in connectivist learning.

Based on the analysis of the cMOOC2.0 data, it was found that pipes and content were equally important to connectivist learning with the goal of knowledge innovation. The structure of knowledge flowing was used to represent pipes, including four characteristics: the breadth, strength, speed, and uniformity, made up of 11 indicators. The content within the pipes was calculated by four characteristics: the breadth, strength, speed, and uniformity of keyword generation, made up of eight indicators. The CIE model was used to code the level of interactions, and correlation analysis and multilinear regression were used to analyze the relationships of pipes or content to interaction levels. The results indicated that the characteristics of pipes had a stronger explanatory power for way-finding interactions and sense-making interactions than that of content (0.558 > 0.186 and 0.838 > 0.746), while they had a weaker explanatory power for innovation interactions than that of contents (0.155 < 0.303) (Tian et al., 2020). This means that way-finding interactions and sense-making interactions depend more on the pipes, requiring learners to take the initiative to express themselves and participate in interactions; innovation interactions, however, are more dependent on the content, which requires learners to have a good grasp of the knowledge itself. Thus, in connectivist learning with the goal of knowledge innovation, the contents within the pipes are as important as the pipes.

The Relationship Between Facilitators and Learners in Connectivist Learning

In connectivist learning, teachers are defined as course facilitators, and shapers and influencers of networks (Wang et al., 2014). They are demonstrators and learners' companions in the journey of learning, but not decision-makers or guides (Dron, 2013). Based on experiences in planning and implementing cMOOCs, Siemens (2010) viewed facilitators as important nodes in networks and defined seven roles for them: magnifying important information or topics in the network, planning and arranging key learning nodes, helping learners do way-finding and sense-making in complex information environments, aggregating fragmented contents, filtering confusing and disturbing information, demonstrating, and staying in the network. By analysing data from the cMOOCs, the research team further tested the facilitators' roles and functions in networked learning.

First, at the beginning of the connectivist learning, facilitators had a significant effect on most learners. As the learning progressed, however, more core learners emerged, and the status of facilitators gradually weakened. The research team used the roles of participants (e.g., academics, business members, administrators, teachers, students, facilitators) as nodes to construct cMOOC1.0 networks and found that facilitators received more attention and replies indicated by relatively higher in-degree (Guo et al., 2020). Further, in the time dimension, at the beginning of learning, there were no apparent groups in the networks, and facilitators were in a position of strong influence, meaning that traditional learners still maintained a viewpoint that teachers were naturally the authorities. As they increasingly got used to connectivist learning, the participants self-organised into various groups. As well, although the facilitators occupied the core position in large groups in the early period, core learners continuously emerged and became the core of their group, even their network status exceeded the facilitators, meaning that the power of facilitators gradually diminished (Xu, 2020).

Second, facilitators' functions in the networks were to promote the building of connections and to influence and shape networks. In cMOOC2.0, it was found that after a live event (organized by the facilitators) was completed, the structure of the social network was more compact, reflected by the highest average degree and density, indicating that the activity that the facilitators participated in increased learners' willingness to interact with each other (Yang et al., 2020). Comparing the parameters of the social networks before and after the facilitators' nodes were deleted, it was shown that after the deletion, the density, complexity, and regularity of the social networks decreased, while the randomness and modularity increased. This means that in the absence of facilitators, learners had their self-organised communities; however, after facilitators joined them, the learners organised themselves following a set of rules, and their connections were closer. In other words, facilitators played the roles of controlling, regulating, maintaining, and enhancing connections, and influenced and shaped the development of networks (Yu et al., 2020).

Discussion and Conclusion

This paper reviews the findings of research conducted over 3 years based on the first cMOOC in China from four aspects, including a) complex network characteristics, b) patterns of knowledge generation, c) patterns of instructional interactions, and d) two important relationships between pipe and content and between facilitators and learners. This research contributes to the development of connectivism in three ways. First, existing viewpoints of connectivism were tested and substantiated based on empirical evidence, such as the roles and functions of facilitators in influencing and shaping network development. Second, the principles of connectivist learning were further developed. For instance, connectivism highlights that learning is the process of building networks. And we further revealed the static and dynamic characteristics of complex networks in connectivist learning. Siemens (2006) proposed the concept of soft knowledge and Downes (2012) raised the concept of the growing mode of knowledge production; this research further examined the connotations and characteristics of networked knowledge and identified three characteristics of knowledge production modes (internal reiteration, group intelligence aggregation, and the bottom-up approach), and interpreted the three roles and functions of knowledge producers. The CIE model proposed four levels of interaction (Wang et al., 2014); this research further explored the time-series relationships between lower-level interactions and higher-level interactions. Third, some viewpoints of existing research on connectivism were improved here. Connectivism emphasizes that “the pipe is more important than the content within the pipe” (Siemens, 2005, para. 33); this research found that, for connectivist learning with the goal of knowledge innovation, the contents within the pipes are as important as the pipes.

Findings from our research also have practical implications for promoting online learning in the new era. As we all know, the COVID-19 outbreak made online learning an important way for students to learn. However, the main format of online learning has been to merely move traditional classroom learning onto the Internet. Although it has been 16 years since connectivist theory was first proposed, there are very few online courses that reflect the characteristics of the new learning theory. In China, the cMOOC developed by this research team is the only connectivist-based online course. The main reason for this gap is insufficient research on the patterns and practical methods of connectivist learning. Although certain results were achieved in recent years, there are still many questions to be answered, such as the evolutional patterns and factors of the three networks, the interplay mechanism between different networks, the modes of instructional design guided by connectivism, the impact of connectivist learning on learners’ capacity development, further exploration of the characteristics of knowledge and its evolutional patterns, the relationship between individual learning and collective learning, and the factors that influence the level of interaction. This study suggests that the above questions be treated as frontline tasks in the fields of online learning, and that by sharing the research findings in China on connectivist theory, researchers and practitioners could be encouraged to conduct more systematic and in-depth research in order to refine connectivist theory and develop e-learning courses more effectively and efficiently.

Acknowledgements

This research is supported by the project "Research on the management of education reform and innovation in the era of 'Internet plus'" funded by The National Natural Science Foundation of China (NSFC) [Grant No. 71834002].

References

Chen, L., Lu, H., & Zheng, Q. H. (2019). 互联网+教育”的知识观：知识回归与知识进化 [Conceptualizing knowledge in “Internet + education:” The nature of knowledge and knowledge evolution]. *Distance Education in China,* (07), 10-18, 92. https://doi.org/10.13541/j.cnki.chinade.2019.07.003

Downes, S. (2005). *An introduction to connective knowledge. https://www.downes.ca/post/33034*

Downes, S. (2012). *Massively open online courses are “here to stay.”* http://www.downes.ca/post/58676

Dron, J. (2013). Soft is hard and hard is easy: Learning technologies and social media. *Form, 13*, 32-43. https://doi.org/10.13128/formare-12613

Guo, Y. J., Chen, L., Xu, L., & Gao, X. F. (2020). 联通主义学习中学习者社会网络特征研究 [Social network characteristics of learners in connectivist learning]. *Distance Education in China*, (02), 32-39, 67, 76-77. https://doi.org/10.13541/j.cnki.chinade.2020.02.004.

Huang, L., & Tan, W. (2017). Survey on process mining in complex evolving social networks. *Computer Engineering and Applications*, *53*(16), 18-28+49. https://doi.org/10.3778/j.issn.1002-8331.1704-0376

Huang, L. Y., Chen, L., Tian, H., & Wang, R. X. (2020). 联通主义学习教学交互的关系及其特征研究 [Instructional interactions in connectivist learning]. *Distance Education in China*, (09), 53-61+77. https://doi.org/10.13541/j.cnki.chinade.2020.09.007

Li, X. S., Chen, L., Wang, W. J., & Li, Y. Y. (2020). 联通主义视阈下的 cMOOC 知识生产的实证研究——基于机器学习的对比分析 [An empirical study of knowledge production from the perspective of connectivism: Comparative analysis based on machine learning]. *Distance Education in China*, (01), 23-34+76. https://doi.org/10.13541/j.cnki.chinade.2020.01.002

Lu, H., & Chen, L. (2019). 知识生产与进化：“互联网+”时代在线课程形态表征与演化研究 [Knowledge production and evolution: Online course representation and evolution in the Internet age]. *Distance Education in China*, *2019*(09), 1-9+92. https://doi.org/10.13541/j.cnki.chinade.2019.09.001

Porter, C. M., & Woo, S. E. (2015). Untangling the networking phenomenon: A dynamic psychological perspective on how and why people network. *Journal of Management*, *41*(5), 1477-1500. https://doi.org/10.1177/0149206315582247

Siemens, G. (2005). Connectivism: A learning theory for the digital age. *International Journal of Instructional Technology and Distance Learning*, *2*(1), 3-10. http://www.itdl.org/Journal/Jan_05/article01.htm

Siemens, G. (2006). *Knowing knowledge.* http://www.elearnspace.org/Articles/networks.htm

Skrypnyk, O., Srec´ko, J., Kovanovic, V., Gasevic, D., & Dawson, S. (2014). Roles of course facilitators, learners, and technology in the flow of information of a cMOOC. *International Review of Research in Open & Distance Learning*, *16*(3), 188-217. https://doi.org/10.19173/irrodl.v16i3.2170

Tawfik, A. A., Reeves, T. D., Stich, A. E., Gill, A., Hong, C., McDade, J., Pillutla, V. S., Zhou, X., & Giabbanelli, P. J. (2017). The nature and level of learner–learner interaction in a chemistry massive open online course (MOOC). *Journal of Computing in Higher Education*, *29*(3), 411-431. https://doi.org/10.1007/s12528-017-9135-3

Tian, H., Chen, L., Huang, L. Y., & Wang, R. X. (2020). cMOOC 学习者知识流动特征与交互水平关系研究[The relationship between the knowledge flow characteristics and the interaction level of cMOOC learners]. *Distance Education in China*, (08), 15-24+76. https://doi.org/10.13541/j.cnki.chinade.2020.08.003

Tirado, M. R., Maraver, L. P., & Hernando, G. (2017). Patterns of participation and social connections in online discussion forums. *Small Group Research*, *48*(6), 639-644. https://doi.org/10.1177/1046496417710726

Wang, H. B., & Chen, L. (2020). 网络化知识的内涵解析与表征模型构建[Conceptualizing networked knowledge and constructing its representation model]. *Distance Education in China*, (05), 10-17+76. https://doi.org/10.13541/j.cnki.chinade.2020.05.002

Wang, H. M., & Chen, L. (2019). cMOOC 微信群社会网络特征及其对学习者认知发展的影响[Impact of social networking features of cMOOC WeChat groups on learners' cognition development]. *Distance Education in China, 11*, 15-23+92. https://10.13541/j.cnki.chinade.2019.11.002

Wang, Z. J., & Chen, L. (2019). 联通主义："互联网+教育"的本体论[Connectivism: The ontology of "Internet Plus Education."] *Distance Education in China*, (08), 1-9+26+92. https://doi.org/10.13541/j.cnki.chinade.2019.08.002

Wang, Z. J., Chen, L., & Anderson, T. (2014). A framework for interaction and cognitive engagement in connectivist learning contexts. *The International Review of Research in Open and Distance Learning*, *15*(2), 121-141. https://doi.org/10.19173/irrodl.v15i2.1709

Xiong, L. Y. (2020). 基于复杂网络建模的联通主义学习交互规律研究[Research on connectivist learning interactive law based on complex network]. [Master's thesis, Beijing Normal University]. http://etd.lib.bnu.edu.cn/Detail?dbID=5&dbCode=ETD1&sysID=76844

Xu, Y. & Du, J. (2021). What participation types of learners are there in connectivist learning: An analysis of a cMOOC from the dual perspectives of social network and concept network characteristics. *Interactive Learning Environments*, 1-18. https://doi.org/10.1080/10494820.2021.2007137

Xu, Y. Q. (2020). cMOOC 个体网络地位与其概念网络特征水平的关系探究[Research on the relationship between individual status in social network and corresponding concept network characteristics in cMOOC]. [Master's thesis, Beijing Normal University]. http://etd.lib.bnu.edu.cn/Detail?dbID=5&dbCode=ETD1&sysID=76127

Yang, Y. H., Zhang, J. J., & Zheng, R. X. (2020). 联通主义学习中社会交互与话题交互的网络化特征[The network characteristics of social interaction and topic interaction in connectivism-based learning]. *Modern Distance Education, 01*, 36-45. https://doi.org/10.13927/j.cnki.yuan.2020.0005

Yu, B., Xu, J. Y., & Tan, L. Q. (2020). 基于社会网络和话题相似度的 cMOOC 学习者聚类研究[Clustering of cMOOC Learners Based on Social Network and Topic Similarity]. *Journal of Open Learning*, *25*(01), 10-21. https://doi.org/10.19605/j.cnki.kfxxyj.2020.01.02

Zhou, J. Y. (2010). 网络教研讨论区的社会网络分析[Social network analysis of online teaching and research forum]. *Distance Education in China, 10*, 37-40. https://doi.org/10.13541/j.cnki.chinade.2010.10.015

Authors

Li Chen, PhD, is a full professor at the Research Centre of Distance Education in Beijing Normal University in China. She has published almost 300 papers and held more than 60 projects in the field of the new principles of online education, connectivism, and educational reform driven by the Internet. Email: lchen@bnu.edu.cn

Yaqian Xu, is a PhD student majoring in distance education at the Beijing Normal University in China. Her research interests include connectivism, online learning analysis, and instructional interaction. Yaqian has published 10 papers in journals. Email: xyq_sky@126.com

CJLT RCAT
Canadian Journal of Learning and Technology
La Revue canadienne de l'apprentissage et de la technologie

Volume 48 (4) Special Issue 2022

Artificial Intelligence in the Fourth Industrial Revolution to Educate for Sustainable Development

L'intelligence artificielle dans la quatrième révolution industrielle pour éduquer au développement durable

Mohamed Ally, *Athabasca University, Canada*

Kirk Perris, *Independent Consultant, Canada*

Abstract

There has been increasing interest in the use of Fourth Industrial Revolution technologies such as artificial intelligence to help achieve the Sustainable Development Goals. Recently, multilateral organizations have sponsored initiatives to make countries aware of the benefits of using artificial intelligence for sustainable development and to educate citizens to improve quality of life. This paper explores aspects of employing artificial intelligence for sustainable development, with a focus on lifelong learning, and inclusive and equitable quality education. Data are drawn from a thematic review of 32 academic peer-reviewed journal articles and interviews with six international experts. Findings include examples of benefits and challenges of artificial intelligence to address sustainable development and education.

Keywords: Artificial intelligence; Fourth Industrial Revolution; 4IR; Online learning; SDG4; Sustainable development goals

Résumé

Il y a eu un intérêt croissant sur l'utilisation des technologies de la quatrième révolution industrielle (4RI), telles que l'intelligence artificielle, pour contribuer à la réalisation des objectifs de développement durable (ODD). Récemment, des organisations multilatérales ont parrainé des initiatives visant à sensibiliser les pays aux avantages de l'utilisation de l'intelligence artificielle pour le développement durable et à éduquer les citoyens pour améliorer la qualité de vie. Cet article explore les aspects de l'utilisation de l'intelligence artificielle pour le développement durable, en mettant l'accent sur l'apprentissage tout au long de la vie et l'éducation de qualité inclusive et équitable. Les données sont tirées d'une revue thématique de 32 articles de journaux académiques évalués par des pairs et d'entretiens avec six experts internationaux. Les résultats comprennent des exemples d'avantages et de défis de l'intelligence artificielle pour aborder le développement durable et l'éducation.

Mots-clés : Intelligence artificielle ; quatrième révolution industrielle ; 4RI ; apprentissage en ligne ; ODD4 ; objectifs de développement durable

Introduction

There has been increasing interest in the use of Fourth Industrial Revolution (4IR) technologies, such as artificial intelligence (AI), the Internet of Things, blockchain, and others, to help achieve the sustainable development goals (SDGs). Recently, organizations such as UNESCO (2019a, 2019b) and the World Economic Forum (2020) have emphasized the use of artificial intelligence for sustainable development. In 2019, two UNESCO conferences were named *Artificial Intelligence for Sustainable Development* and *International Conference on Artificial Intelligence and Education: Planning Education in the AI Era: Lead the Leap*. Leapfrogging has been a common metaphor in relation to sustainable development ("The Leapfrog Model", 2017), with the notion that lessons learned from western industrialisation can expedite modernization elsewhere. China's state-led model was a case in point (Xue et al., 2018), as were the four Asian Tigers (Hong Kong, Singapore, South Korea, and Taiwan) that pre-dated China's rise starting in the late 1970s by about 20 years. With a narrower focus, this paper contemplates how far the emerging world can gain, if not exploit, the promise of the 4IR in the context of education, which is universally agreed as a cornerstone to sustainable development. To advance this conversation, it is imperative to consider alongside the perceived benefits, the existing challenges. Top of the list is infrastructure (Fayomi et al., 2019; Pollitzer, 2019), with other matters that include security, ethics, and employment. Those in repetitive task or low skilled jobs, where a large proportion of the world's workforce is located, are most at-risk to the onslaught of the 4IR, and particularly as it relates to automation (Habanik et al. 2019; Oberc et al., 2019). While governments are increasingly aware of these looming realities, they are also prone to being reactive rather than proactive on issues, particularly in functional democracies, where political cycles focus politicians' attention on the near-term rather than the long-term. As a means to consider what opportunities lie ahead, this paper draws on inputs from AI experts around the world on what is needed to prepare and actively participate in the 4IR. Aspects on the development of artificial intelligence for sustainable development, and taking a multidisciplinary approach to consider uses, innovations, ethics, access, privacy, security, and so on will be delineated. The aim is to develop an informed, collective understanding of the benefits and challenges in present and which may arise from the subsequent adoption of AI for achieving the SDGs, especially in relation to SDG4, which focuses on education (Visvizi, 2022).

Guiding this paper are the following two research questions:

1. What role can AI play to educate citizens for sustainable development?
2. What role can AI play to help achieve the sustainable development goals?

The Fourth Industrial Revolution and Sustainable Development

Different sectors of society are experiencing the 4IR. It is driven by the digital revolution, which combines the physical, digital, and biological domains into daily life. Tools that were previously offline and required our physical presence to operate are now controlled remotely and at a finger's touch facilitated through the Internet. The underlying premise of the 4IR is to inform the next level of societal advancement, as was the case in the three earlier industrial revolutions. In present day, the 4IR is predicated on the ubiquity, connectivity, and independence of digital technologies. For sustainable development, the question remains about how 4IR may alleviate poverty, widen access to quality learning, and protect the environment.

The UNESCO report *Meeting Commitments: Are Countries on Track to Achieve SDG4?* indicated that meeting the SDG targets were not on track and were exacerbated by the inability to collect the necessary data (2019b). Artificial intelligence is one proposed solution to automate data mining. Such advancements cannot exist outside the social world. Citizens need to be educated and society must have some say over how AI will affect their lives. The world is irreversibly interconnected, and this means enhanced capabilities to address enduring economic, social, and environmental problems.

Artificial intelligence can be defined as "a machine-based system that can, for a given set of human-defined objectives, make predictions, recommendations or decisions influencing real or virtual environments" (Vincent-Lancrin & van der Vlies, 2020, p. 7). The link to education is in the provision of flexible and personalised learning that can more broadly lead to the acquisition of skills, improved livelihoods, and ultimately sustainable development (Rizk, 2020; Wozniak, 2020). The United Nations (UN) has defined sustainable development as a movement for ensuring sustainable well-being for all United Nations (2015). Through the 17 sustainable development goals, led and coordinated by UNESCO, the UN has aimed to address the persisting global issues of poverty, inequality, conflict, climate change, and environmental degradation (Ghobakhloo, 2020). Ultimately the intent is for all sectors of society to embrace efforts to improve the livelihoods of the world's residents, and particularly the marginalized (Pollitzer, 2019; Rosa, 2017; United Nations, 2015). The link between AI and the SDGs can be considered in the context of empowerment. Rubin and Brown (2019) posited that artificial intelligence was still in a nascent stage but its applications to learn about students' interests, habits, and patterns in order to promote learning experiences based on unique identified needs, was emerging.

> If this (artificial intelligence) technology is to be accessible to all, it must be taught everywhere. It is through education that it will be placed in the hands of those who need it most. And I guarantee you that if you give them the means, people will find solutions to their own problems. (Cissé, 2018, p. 20)

UNESCO has been exploring the possible contributions of AI to inclusive education and assessing its potential impact on the future of learning (Azoulay, 2018, p. 38). Artificial intelligence has the potential to improve the welfare of people; contribute to positive sustainable global economic activity; increase innovation and productivity; and help with responses to key global challenges, such as climate change, health crises, resource scarcity, and discrimination (OECD, 2019b). The OECD and other organisations have seen the potential for AI to contribute to achieving the SDGs with specific acknowledgment of its role in education (OECD, 2019a, p. 4).

Literature Review

Education 4.0 in Sustainable Development

The *United Nations Sustainable Development 2030 Agenda* contains 17 SDGs and 169 targets intended to help guide all sectors of society to improve the livelihoods of the world's residents (Pollitzer, 2019; Rosa, 2017; United Nations, 2015). SDG4 on education aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (Rosa, 2017, p. 14).

The link to AI in education is personalisation and self-organising relative to instruction and support to learners (Mitra, 2014, 2019). Learning will move toward individualisation and learner centeredness, due to AI (Aker & Herrera, 2020; Chai & Kong, 2017; Mitra, 2014; Popenici & Kerr, 2017). Emerging technologies will dramatically change the role of teachers, with many becoming digital teachers, using deep-learning technologies such as AI (Ally, 2019; Ally & Wark, 2019a). The World Economic Forum (2017) foresaw teachers having to adopt AI to teach in the 4IR. Are these kinds of interventions achievable in countries at all income levels? Not at present. There is little reason, however, to overlook the role of AI in varied contexts and to consider what uses exist, or potentially exist, supported by conditions, cultures, and histories that are locally situated.

Online Learning and Machine Learning in Education for Sustainable Development

Characterized as the desire for interactive, co-created, personalised, on-demand, and perpetual learning, online learning is surging in demand with the transition into the 4IR era (Ally & Wark, 2019b; Buasuwan, 2018; Wan Chik & Arokiasamy, 2019). Increasingly, traditional formal classroom-based learning is being supplanted by online and mixed-reality learning environments that can provide timely and relevant learning (Block et al., 2018; Grodotzki et al., 2018; Mavrikios et al., 2019; Mourtzis et al., 2018). Moreover, escalating access to online and mobile learning platforms (Aziz Hussin, 2018; Bhattacharjee et al., 2018; Block et al., 2018; J. Chen et al., 2018; Jia et al., 2019; Lou, 2018; Stock et al., 2018), including a recent initiative to develop a global, AI-enabled, open-source, online learning platform (Duraiappah, 2018), suggests that in the near future, online learning will supersede the demand for traditional face-to-face learning (Ally & Wark, 2019b).

Duraiappah's (2018) article, "Artificial Intelligence for Education," described an online prototype platform called Collective Human Intelligence that allows, "educators and learners to develop curriculum, lesson plans and assessments in an interactive, immersive and experiential environment, which is supported by AI that is able to provide feedback to students and educators of progress and suggestions to improve learning" (p. 1). One feature of this globally accessible online platform is the assignment of a personal bot to a child. This bot draws upon collective knowledge from learners across the globe, while tailoring instructional activities and tasks to meet the unique needs of the learner to whom it is assigned.

Machine learning (ML) is a sub-field of AI associated with machines' ability to learn inductively (Buckreus & Ally, 2020). Machine learning applications are designed to process sets of historical observations (data records) to infer new patterns or rules arising from the data. Whenever the data are changed, an ML algorithm *learns*. An algorithm learns in the sense that it picks up the modified patterns in each data set and then presents or predicts a new result to personalise the instructional activities for the learner. The system will learn about the learner as the two progresses, then make decisions that will optimise instructional activities.

Kučak et al. (2018) conducted a systematic review to determine the value of machine learning in the field of education. They concluded that ML made a significant contribution in numerous areas of education: (a) prediction of learner performance, (b) fair and equitable assessment of learning, (c) improved learner retention, and (d) provision of administrative duties for educators. Moreover, ML could offer personalised assessment by eliminating standardised testing, and providing "constant feedback to teachers, students and parents about how the student learns, the support they need and the progress they are making towards their learning goals" (p. 409).

Methodology

Data was generated from a review of relevant literature and interviews with international experts in 4IR, AI, and other emerging technologies. The aim was to answer the following research questions:

1. What role can AI play to educate citizens for sustainable development?
2. What role can AI play to help achieve the sustainable development goals?

The literature included in this study came from four sources: (a) the researchers' personal libraries, (b) a systematic review of pertinent peer-reviewed journal articles, (c) final reports from world organisations such as the World Economic Forum and UNESCO, and (d) interviewee publications, reports, links to web resources, and other recommended resources. This study used well-established systematic review processes (Gough et al., 2012; Hemingway & Brereton, 2009; Oakley, 2012). Ethics approval from an accredited Canadian university was obtained to conduct the study.

Systematic Literature Review

A university meta-database search engine was used to conduct a comprehensive search of relevant academic peer-reviewed journal articles. Three inclusion criteria were established. First, the articles had to be in an English-language, peer-reviewed journal located in a university-subscribed or open-access journal database and second, published between January 1, 2017, and December 31, 2019. Third, the article content had to address at least one of the research questions. A total of 219 titles were initially selected (see Table 1).

Table 1

Number of Journal Articles Identified by Journal Database

Journal database	Number of journal titles
Science direct	125
Academic search complete	56
Business source complete	32
SocINDEX with full text	13
Academic one file	12
Expanded academic ASAP	5
General one file	4
Canada In Context	3
Emerald insight	3
General reference center gold	3
Literature resource center	3
Student resources in context	3
Communication & mass media complete	2
CINAHL plus with full text	1
InfoTrac computer database	1
Total number of titles	266
Less: duplicates	– 47
Total number of unique titles	219

After several rounds of discussion and consensus building, 78 were selected. There were 36 articles that did not address at least one of this study's research questions. A total of 32 articles matched all the inclusion criteria for analysis. (These 32 articles are listed with an asterisk in the reference section.)

Interviews with 4IR Experts

Based upon their knowledge and expertise in the identified topic areas, 48 4IR international experts from academic, government, private enterprise, and civil service sectors were invited to join the study. Of these, 12 experts completed interviews, and herein are referred to as respondents. Recorded interviews were conducted by telephone or online. Each respondent was asked to edit and verify the transcription of their interview before the transcript was processed for analysis purposes.

The results reported herein include data from six interviews. They were selected for their ability to provide a rich picture of the phenomena under study, in a manner that added greatest value in terms of the project's aims. In terms of experience, the experience in the 4IR sector ranged from four to more than 30 years. At the time of the study, five were employed in the field of academia. Three taught university classes; one of these was also an administrative leader. Two respondents worked in non-teaching university positions.

Results and Discussion

This section is based upon cumulative data results drawn from six interviews and the previously described literature sources.

Interview Data Analysis Process

The highest level of coding labels (or "parent codes") in the qualitative coding framework were drawn from the main sections of the interview script. Sub-code labels (or "child codes") and sub-sub-code labels (or "grandchild codes") were established under the parent codes as two researchers coded the first two interview transcripts together. The first researcher then coded a third transcript, and the second researcher reviewed the coding, ascertaining 100% agreement with the first researcher. Coding of the remaining three transcripts followed this pattern of the first researcher doing the initial coding and the second coder verifying the results. Between coders, 100% agreement was achieved throughout this process.

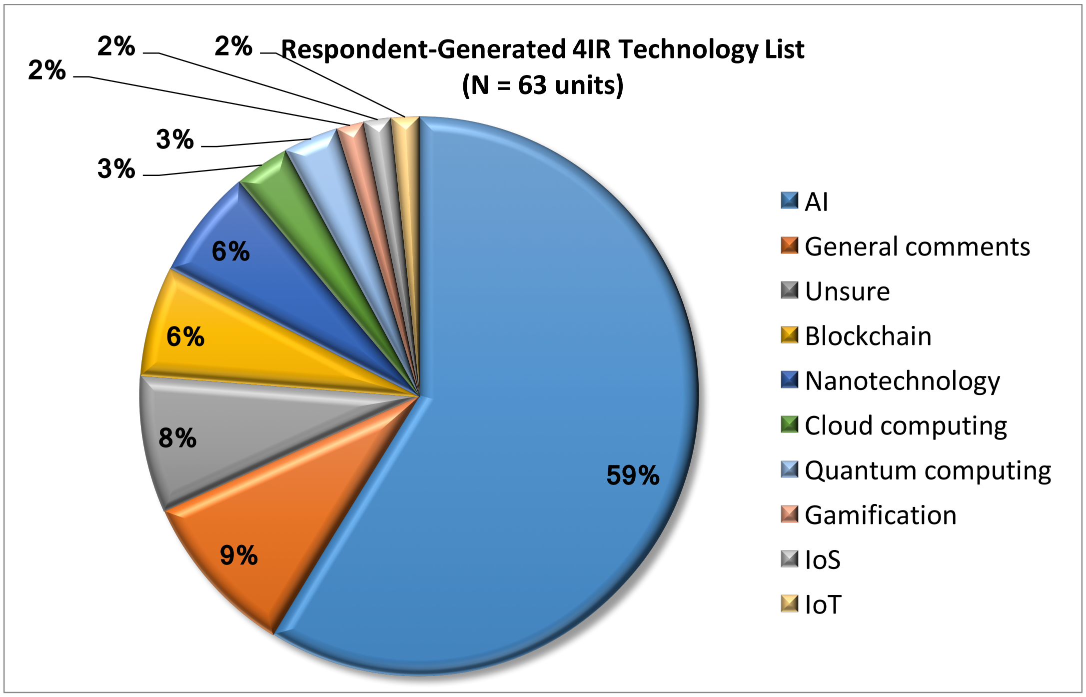
What Are the Emerging Technologies?

A total of 63 units were coded in response to the interview question to list the emerging technologies. The technology most discussed by respondents was AI (n = 37 units, or 59 per cent of all units coded to this category; see Figure 1). One respondent-recommended resource was the book *Artificial Intelligence in Education: Promises and Implications for Teaching and Learning* (Holmes et al., 2019), wherein a taxonomy of AI technologies for learning was presented. This taxonomy included intelligent tutoring systems, dialogue-based tutoring systems, exploratory learning environments, automatic writing evaluation, learning network orchestrators, and AI-driven language learning.

The pervasiveness of AI technologies for educational purposes was evident not only in the interview discussions but also in the literature. Twenty-five of the 32 articles mentioned AI in general or discussed specific AI technologies in relation to the SDGs.

Figure 1

List of Technologies Generated by Respondents



Note. (N = 63 units; 1 unit = 1 sentence, expressed by percentage)

How Can These Emerging Technologies Be Used in Education?

Data collected from the reviewed literature and respondent interviews focused upon four key themes in addressing how emerging 4IR technologies could be used to educate the masses. These themes were:

- access to learning
- lifelong learning
- employing AI learning technologies
- personalised learning

Access to Learning

A prevalent theme emerging from the data was access to learning. When talking about current access to education, one respondent relayed the following observation:

> At these [international] conferences I met people from the developing world, and it was clear, time and time again, that they were saying, "Why are we talking about AI in education when we don't even have the infrastructure? We don't have electricity. We don't have Internet access. We don't have the hardware that is necessary."

The sentiments expressed by interviewees on infrastructure was echoed in the reviewed literature (Fayomi et al., 2019), with another interviewee noting the bias in AI toward rich world countries. That said, there is better infrastructure around the globe than ever before with improved links in particular between urban and rural centres (Fennell et al., 2018). It has only been 15 years since the iPhone's launch in 2007 ushering in rapid expansion of smartphones worldwide, including numerous brands that are as inexpensive as USD $50. As well, the cost for technology has decreased and continues to be inversely proportional with computing power. Part of the problem, noted by one interviewee is that,

> decision-makers are not AI practitioners or trained in AI. They're the ones that we're relying on to create policies that allow companies to grow, yes, but also to keep our data and institutions secure, and keep our personal data and information in our hands. They are supposed to create the policies, the curricula, and the plans for education going forward. And yet very few have a deep understanding of what AI can do or how it works.

As it relates to education, governments and educational decision-makers need to be aware that AI is expected to significantly transform the way that educators work by offering teaching aids and relieving them of repetitive or mundane tasks, such as keeping records and sending out notifications or reminders (Ellahi et al., 2019). Furthermore, it is anticipated that AI will revolutionise personalised learning, improve access to knowledge, and potentially foster greater inclusivity (Azoulay, 2018; Duraiappah, 2018; Hodson, n.d.; UNESCO, 2019a).

Lifelong Learning

Most of the literature and interview data surrounded the recognition of lifelong learning in the 4IR era. Some of the data discussed how emerging technologies, especially AI, might support lifelong learning goals. One respondent concluded the interview discussion on lifelong learning by postulating, "digital assistants could be used in ways to help with setting lifelong learning goals."

This is aligned with how Kemato (2018) detailed how AI could be used to create parallel micro-level skill development models for a learner, by not only tracking skill acquisition but also presenting job opportunity choices and career path scenarios. When prerequisite skills are absent, AI that is cognisant of existing curricular options could then recommend learning resources and track the learner's progress towards the attainment of these skills. "In other words, AI can produce online courses from identified skills and so bring vocational training and lifelong learning for billions of learners" (p. 25).

Employing AI Learning Technologies

A myriad of examples of AI learning technologies and how they can be used in the 4IR emerged from the reviewed literature and interview data. The most common AI topics associated with this theme focused upon immersive learning, machine learning, and learning platforms. AI-driven game-based learning was mentioned in some articles and one interview.

General statements or examples were provided of how emerging technologies can be used to facilitate personalised learning, as the following interview comment illustrates:

> So, this is a broad concept, and there are a lot of technologies that are developed around this concept, like how you personalise learning to a particular individual speed, or liking, or all other things. So, if they are doing things at their own pace, they can always try the same thing even if they are doing it wrong, they can try it for 10–15 times.

What AI Technologies Can Contribute to Sustainable Development?

When interviewees were asked to identify what emerging 4IR technologies could contribute to sustainable development, the prevalent response was, “All of them.” As one respondent put it, these technologies “optimise human behaviours and human capabilities.” Another respondent said:

> There’s nothing in this world that will not be impacted by AI technology. In terms of 4IR technologies, I would say that AI is by far the most mature, is the one having the most current impact, and in the long run, the one that will have the deepest and most ramifications on society.

Interviewees provided several examples where AI technologies can enhance inclusivity and empowerment for global citizens. To illustrate, one interviewee pointed out that the Internet represents only five per cent of the world’s languages, with English persisting as the digital lingua franca (Hariharasudan & Kot, 2018). The interviewee described how one learning/neural network technology, natural language processing, offers an equitable solution:

> I think natural language processing is the crux of pretty much everything if we want to talk about equitable access, or worldwide or international equality in any way going forward through the fourth industrial revolution. So, I think these types of translation-based AIs and really anything that can support minority language speakers in accessing information is going to be the most helpful.

According to another interviewee, the employment of natural language processing also facilitates better communication between governments, other public institutions, and citizens, especially in countries where numerous languages co-exist, as in India or Papua New Guinea.

One pilot project in India explored ways in which AI can facilitate the prediction and diagnosis of prevalent diseases, such as heart ailments (Javaid & Haleem, 2019). Another project focused on the development of an AI app that can read and transform medical practitioners’ handwriting into various digital formats to facilitate the processing of medical prescriptions and other medical information (Javaid & Haleem, 2019). There are also chatbots being designed to help patients’ complete forms; others are employed to reduce patients’ anxiety. Global research projects could examine the viability of such initiatives for providing better health services to disadvantaged citizens around the world. The education sector can learn from how AI is used in non-educational sectors. Cues from some sectors can inform progress in others and a multidisciplinary approach to solving issues is also part of the SDGs, and in particular, SDG17, which focuses on partnerships to reach the SDGs by 2030.

Conclusion

What Role Can the 4IR and AI Play in Education?

The greatest role that the 4IR and AI can play in sustainable development is to improve accessibility. In the context of AI, equal access to technologies, employment opportunities and education are key. A prominent theme arising from this study is the pivotal function of education in fostering greater equality. Yet study results also underscore the urgent need to educate and support teachers, learners, and other global citizens in the transition to the 4IR era and its influence on education. Future projects and other global initiatives could play a vital role in facilitating these transformations by offering educational stakeholders timely, inexpensive, and professional development and training resources, such as making Massive Open Online Courses (MOOCs) and Open Education Resources (OERs) more intelligent to cater for learners' individual needs.

Educational briefs, brochures, and resources for government administrators, policy makers, educational stakeholders and the general public that counter the myths and fears surrounding 4IR technologies are crucial (Xue et al., 2018). Interviews with expert respondents clarified that teachers do not need to have advanced training in AI but do require a basic understanding of AI to address, if not neutralise, their misunderstandings or lack of knowledge, and by association create an environment for their learners that embraces rather than excludes technology. Government administrators, policy makers, and educational stakeholders need exposure to how 4IR technologies can be used for sustainable development in their regional or national contexts. Future global activities could employ 4IR technologies to create and distribute educational packages that describe and exemplify how these technologies can be used for the benefit of humans.

Also, 4IR technologies can be incorporated into future global enterprises to track, monitor, and suggest recommendations for improved services to global citizens. For example, AI and blockchain can be employed with respect to a particular educational initiative; to record, monitor, assess and make recommendations for improvement, or access student records and credentials. The blockchain can offer an open, transparent, reliable, and trustworthy ledger of interactions and transactions among all stakeholders (G. Chen et al., 2018; Hidayatno et al., 2019; Hughes et al., 2019; Muhuri et al., 2019; Stock et al., 2018). Artificial intelligence would learn from these activities and thereby be able to offer suggestions for future projects.

Other needed resources are educational packages aimed at developing: (a) essential numeracy, literacy, and digital skills, (b) social, moral, and critical thinking capacities, along with creative, problem-solving capacities, that engender emotional intelligence, flexibility and adaptability, and (c) lifelong learning opportunities (Ally & Wark, 2019a, 2019b; Aoki, 2020; Aziz Hussin, 2018; Brown & Keep, 2018; Butler-Adam, 2018; Gusmão Caiado et al., 2018; Lou, 2018; Mourtzis et al., 2018).

What Role Can 4IR and AI Play in Sustainable Development?

Artificial intelligence and other 4IR technologies can be used to enhance cultural, social, economic, and environmental sustainability if governments, industry, and citizens have the access and know-how to employ these technologies. Donaires et al. (2018) identified three levels of societal effort to achieve sustainability: individual, organisational, and worldwide. The most critical step towards sustainability is at the individual level, where personal attitudes about the right to lead a self-centred lifestyle can be replaced by a willingness to embrace co-operative decision making and living, as well as an ethos of self-denial and self-sacrifice (de Raadt & de Raadt, 2014). The challenge faced at the organisational level is how to balance economic demands against internal social and environmental costs when developing a systematic approach to sustainability (Donaires et al., 2018). Globally, the dilemma is how to measure, monitor, and assess what progress is being made towards global sustainability (Donaires et al., 2018; Schwaninger, 2015; UNESCO, 2019b).

Artificial intelligence and other 4IR technologies can be employed to increase equality among global citizens as the world enters the 4IR era. The primary key to achieving the SDGs is the provision of quality education for all. Future global projects need to support research, innovation, financial initiatives, and other incentives aimed at providing equitable, affordable access to 4IR technologies.

Future of AI for Education in the Fourth Industrial Revolution

Emerging digital technologies will converge to create cyber-physical systems that will transform how factories operate, how manufacturing processes are controlled, how healthcare and transport services are rendered, and what kind of consumer markets can be created (Luthra & Mangla, 2018; Mourtzis et al., 2019; Pollitzer, 2019; Zabidin et al., 2019). Under the cloud of the 2019 Coronavirus pandemic, education systems– though not universally –have shifted to an online format that is increasingly learner centred. The use of AI can personalise learning for individual learners, simulating intelligent tutors. According to the UNESCO Institute for Statistics (2016), the world needs 69 million teachers to achieve SDG4. Having intelligent tutors could compensate for this shortage of teachers.

The UNESCO report *I'd Blush if I Could* (West et al., 2019) detailed the global gender divide: "Today, females are 25 per cent less likely than males to know how to leverage digital technology for basic purposes, four times less likely to know how to programme computers and 13 times less likely to file for a technology patent" (p. 4). The report pointed out that AI technologies often reinforce gender bias. This phenomenon is likely due to the dominant number of AI designers who are male, and some whom have modeled chauvinistic behaviour through disparaging remarks or subtle actions (Richardson, 2015; West et al., 2019). An effective way to reduce gender bias in AI is for countries, international organisations, and educational institutions to continue to promote gender equality policies, and to financially support the inclusion of females in digital education programmes, as well as to provide incentives that encourage industries to hire women in the field of AI.

Educating citizens around the world will be the key to help achieve the SDGs (Doucet et al., 2018). Futurists predict that education will become self-organising, and technology will play a major role in delivering instruction and support to learners (Mitra, 2014, 2019). In this context, learning will increasingly become individualised and learner-centred due to 4IR technologies such as AI, learning analytics, and the Internet of Things (IoT) (Chai & Kong, 2017; Popenici & Kerr, 2017). The 4IR era will certainly change the role of teachers, who will then become 4IR or digital teachers, using deep-learning technologies such as AI, robotics, big data, and the IoT (Ally, 2019; Bryant et al., 2020). The AI divide and 4IR divide will need to be bridged so that teachers and learners can be well-prepared to use emerging technologies in teaching and learning. In addition, education will play an important role in assisting the world with transitioning into the 4IR to achieve the UNESCO SDGs by 2030. This will require a new lifelong, learner-centred educational paradigm, and learning environments that foster critical thinking, innovation, moral judgment, social inclusion, and ecological sustainability (Aoki, 2020). AI and machine learning can complement other digital education initiatives for educating citizens to help achieve the SDGs.

We posit that 4IR technologies, which are underutilised in education when compared to other sectors in society, provide an avenue for education to contribute to sustainable development goals. Outside of the education sector, organisations need to educate employees on social skills and trustworthiness so that AI can be used for good in society (Smolenski, 2016). Audrey Azoulay (2018), the Director-General of UNESCO, commented:

> AI can be a fantastic opportunity to achieve the goals set by the 2030 Agenda, but that means addressing the ethical issues it presents. AI can allow better risk assessment; enabling more accurate forecasting and faster knowledge-sharing; by offering innovative solutions in the fields of education, health, ecology, urbanism, and the creative industries; and by improving standards of living and our daily well‐ being. (p. 37)

Vinuesa et al. (2020) claimed no study has examined the merits of AI to inform the UNESCO SDGs, despite the potential of AI. Artificial intelligence use for education and sustainable development relies on multiple sectors of society coming together in research and development on the topic.

References

An asterisk (*) denotes an article that matched all the study's inclusion criteria.

Aker, M., & Herrera, L. J. P. (2020). Smart literacy learning in the 21st century: Facilitating PBSL pedagogic collaborative clouds. In S. Yu, M. Ally, & A. Tsinakos (Eds.), *Emerging technologies and pedagogies in the curriculum* (pp. 429–446). Springer.

Ally, M. (2019). Competency profile of the digital and online teacher in future education. *International Review of Research in Open and Distributed Learning, 20*(2), 302–318. https://doi.org/10.19173/irrodl.v20i2.4206

Ally, M., & Wark, N. (2019a, September). *Learning for sustainable development in the Fourth Industrial Revolution.* In Proceedings of the Pan-Commonwealth Forum 9 (PCF9). Commonwealth of Learning. http://oasis.col.org/handle/11599/3393

Ally, M., & Wark, N. (2019b, November). *Online education in the Fourth Industrial Revolution era.* [Paper presentation]. International Council on Distance Education (ICDE) World Conference on Online Learning (WCOL) 2019, Dublin, Ireland. https://wcol2019.ie/wp-content/uploads/presentations/CP_052,%20ALLY.pdf

Aoki, K. (2020). Technologies for lifelong and lifewide learning and recognition: A vision for the future. In S. Yu, M. Ally, & A. Tsinakos (Eds.), *Emerging technologies and pedagogies in the curriculum* (pp. 41–52). Springer.

*Aziz Hussin, A. (2018). Education 4.0 made simple: Ideas for teaching. *International Journal of Education and Literacy Studies, 6*(3), 92-98. http://dx.doi.org/10.7575/aiac.ijels.v.6n.3

Azoulay, A. (2018). Making the most of artificial intelligence. *The UNESCO Courier, 3*(July-September), 36-39. https://en.unesco.org/courier/2018-3/audrey-azoulay-making-most-artificial-intelligence

*Bhattacharjee, D., Paul, A., Kim, J. H., & Karthigaikumar, P. (2018). An immersive learning model using evolutionary learning. *Computers & Electrical Engineering, 65*, 236–249. https://doi.org/10.1016/j.compeleceng.2017.08.023

*Block, C., Kreimeier, D., & Kuhlenkötter, B. (2018). Holistic approach for teaching IT skills in a production environment. *Procedia Manufacturing, 23,* 57–62. https://doi.org/10.1016/j.promfg.2018.03.161

*Brown, P., & Keep, E. (2018). Rethinking the race between education and technology. *Issues in Science and Technology, 1,* 31–39.

Bryant, J., Heitz, C., Sanghvi, S., & Wagle, D. (2020). *How artificial intelligence will impact K-12 teachers.* McKinsey & Company. https://www.mckinsey.com/industries/social-sector/our-insights/how-artificial-intelligence-will-impact-k-12-teachers

*Buasuwan, P. (2018). Rethinking Thai higher education for Thai 4.0. *Asian Education and Development, 7*(2), 157–173. https://doi.org/10.1108/AEDS-07-2017-0072

Buckreus, K., & Ally, M. (2020). "Smart" practices: Machine intelligence for transforming pedagogy and learning. In S. Yu, M. Ally, & A. Tsinakos (Eds.), *Emerging technologies and pedagogies in the curriculum* (pp. 53–74). Springer.

*Butler-Adam, J. (2018). The Fourth Industrial Revolution and education. *South African Journal of Science, 114*(5/6), 1. https://doi.org/10.17159/sajs.2018/a0271

Chai, C. S., & Kong, S. C. (2017). Professional learning for 21st century education. *Journal of Computers in Education, 4*(1), 1-4. https://doi.org/10.1007/s40692-016-0069-y

*Chen, G., Xu, B., Lu, M., & Chen, N.-S. (2018). Exploring blockchain technology and its potential applications for education. *Smart Learning Environments, 5*(1), 1. https://doi.org/10.1186/s40561-017-0050-x

*Chen, J., Yin, X., & Mei, L. (2018). Holistic innovation: An emerging innovation paradigm. *International Journal of Innovation Studies, 2*(1), 1–13. https://doi.org/10.1016/j.ijis.2018.02.001

Cissé, M. (2018). Democratizing AI in Africa. *The UNESCO Courier, 3*(July-September), 20-21. https://en.unesco.org/courier/2018-3/democratizing-ai-africa

de Raadt, J. D. R., & de Raadt, V. D. (2014). *From multi-modal systems thinking to community development: Regaining our humanity through community.* Melbourne Centre for Community Development. http://www.melbourneccd.com/books/community.pdf

*Donaires, O. S., Cezarino, L. O., Caldana, A. C. F., & Liboni, L. (2018). Sustainable development goals: An analysis of outcomes. *Kybernetes, 48*(1), 183–207. https://doi.org/10.1108/K-10-2017-0401

Doucet, A., Evers, J., Guerra, E., Lopez, N., Soskil, M., & Timmers, K. (2018). *Teaching in the fourth industrial revolution: Standing at the precipice*. Routledge. https://doi.org/10.4324/9781351035866

Duraiappah, A. K. (2018). Director's message: Artificial intelligence for education. *The Blue DOT, 9*, 1. https://mgiep.unesco.org/the-blue-dot-issue-9

*Ellahi, R. M., Ali Khan, M. U., & Shah, A. (2019). Redesigning curriculum in line with Industry 4.0. *Procedia Computer Science, 151*, 699–708. https://doi.org/10.1016/j.procs.2019.04.093

*Fayomi, O. S. I., Okokpujie, I. P., Fayom, G. U., & Okolie, S. T. (2019). The challenge of Nigeria researcher in meeting up with sustainable development goal in 21st century. *Energy Procedia, 157*, 393–404. https://doi.org/10.1016/j.egypro.2018.11.204

*Fennell, S., Kaur, P., Jhunjhunwala, A., Narayanan, D., Loyola, C., Bedi, J., & Singh, Y. (2018). Examining linkages between smart villages and smart cities: Learning from rural youth accessing the internet in India. *Telecommunications Policy, 42*(10), 810–823. https://doi.org/10.1016/j.telpol.2018.06.002

Ghobakhloo, M. (2020). Industry 4.0, digitization, and opportunities for sustainability. *Journal of Cleaner Production, 252*, 1–18. https://doi.org/10.1016/j.jclepro.2019.119869

Gough, D., Oliver, S., & Thomas, J. (2012). Introducing systematic reviews. In D. Gough, S. Oliver, & J. Thomas (Eds.), *An introduction to systematic reviews* (pp. 1–16). SAGE Publications. https://uk.sagepub.com/en-gb/eur/an-introduction-to-systematic-reviews/book245742

*Grodotzki, J., Ortelt, T. R., & Tekkaya, A. E. (2018). Remote and virtual labs for Engineering Education 4.0. *Procedia Manufacturing, 26*, 1349–1360. https://doi.org/10.1016/j.promfg.2018.07.126

*Gusmão Caiado, R. G., Leal Filho, W., Quelhas, O. L. G., Luiz de Mattos Nascimento, D., & Ávila, L. V. (2018). A literature-based review on potentials and constraints in the implementation of the Sustainable Development Goals. *Journal of Cleaner Production, 198*, 1276–1288. https://doi.org/10.1016/j.jclepro.2018.07.102

*Habanik, J., Grencikova, A., & Krajco, K. (2019). The impact of new technology on sustainable development. *Engineering Economics, 30*(1), 41–49. https://doi.org/10.5755/j01.ee.30.1.20776

*Hariharasudan, A., & Kot, S. (2018). A scoping review on digital English and Education 4.0 for Industry 4.0. *Social Sciences, 7*(11), 227. https://doi.org/10.3390/socsci7110227

Hemingway, P., & Brereton, N. (2009). In Hayward Medical Group (Ed.), *What is a systematic review?* http://www.medicine.ox.ac.uk/bandolier/painres/download/whatis/syst-review.pdf

*Hidayatno, A., Destyanto, A. R., & Hulu, C. A. (2019). Industry 4.0 technology implementation impact to industrial sustainable energy in Indonesia: A model conceptualization. *Energy Procedia, 156*, 227–233. https://doi.org/10.1016/j.egypro.2018.11.133

Hodson, J. (n.d.). *Can artificial intelligence help us achieve universal quality education?* UNESCO. https://mgiep.unesco.org/article/can-artificial-intelligence-help-us-achieve-universal-quality-education

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning.* Center for Curriculum Redesign. https://curriculumredesign.org/our-work/artificial-intelligence-in-education/

*Hughes, L., Dwivedi, Y. K., Misra, S. K., Rana, N. P., Raghavan, V., & Akella, V. (2019). Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda. *International Journal of Information Management, 49*, 114–129. https://doi.org/10.1016/j.ijinfomgt.2019.02.005

*Javaid, M., & Haleem, A. (2019). Industry 4.0 applications in medical field: A brief review. Current *Medicine Research and Practice, 9*(3), 102–109. https://doi.org/10.1016/j.cmrp.2019.04.001

*Jia, M., Komeily, A., Wang, Y., & Srinivasan, R. S. (2019). Adopting Internet of Things for the development of smart buildings: A review of enabling technologies and applications. *Automation in Construction, 101*, 111–126. https://doi.org/10.1016/j.autcon.2019.01.023

Kemato, H. (2018). How AI will change education. *The BlueDot, 9,* 25–26. https://d27gr4uvgxfbqz.cloudfront.net/files%2Fb5f1be58-9162-4a68-85d1-125bd6ecca60_The%20Blue%20Dot%209.pdf

*Kučak, D., Juričić, V., & Đambić, G. (2018). Machine learning in education — a survey of current research trends. *Annals of DAAAM & Proceedings, 29*, 406–410. https://doi.org/10.2507/29th.daaam.proceedings.059

*Lou, Y. (2018). Designing interactions to counter threats to human survival. She Ji: *The Journal of Design, Economics, and Innovation, 4*(4), 342–354. https://doi.org/10.1016/j.sheji.2018.10.001

*Luthra, S., & Mangla, S. K. (2018). Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies. *Process Safety and Environmental Protection, 117*, 168–179. https://doi.org/10.1016/j.psep.2018.04.018

*Mavrikios, D., Alexopoulos, K., Georgoulias, K., Makris, S., Michalos, G., & Chryssolouris, G. (2019). Using holograms for visualizing and interacting with educational content in a Teaching Factory. *Procedia Manufacturing, 31*, 404–410. https://doi.org/10.1016/j.promfg.2019.03.063

Mitra, S. (2014). The future of schooling: Children and learning at the edge of chaos. *Prospects, 44*, 547–558. https://doi.org/10.1007/s11125-014-9327-9

Mitra, S. (2019, September). *The future of learning* [Keynote speech]. Pan-Commonwealth Forum 9 (PCF9), Edinburgh, Scotland.

*Mourtzis, D., Boli, N., Dimitrakopoulos, G., Zygomalas, S., & Koutoupes, A. (2018). Enabling small and medium enterprises (SMEs) to improve their potential through the Teaching Factory paradigm. *Procedia Manufacturing, 23*, 183–188. https://doi.org/10.1016/j.promfg.2018.04.014

*Mourtzis, D., Vasilakopoulos, A., Zervas, E., & Boli, N. (2019). Manufacturing system design using simulation in metal industry towards Education 4.0. *Procedia Manufacturing, 31,* 155–161. https://doi.org/10.1016/j.promfg.2019.03.024

*Muhuri, P. K., Shukla, K., & Abraham, A. (2019). Industry 4.0: A bibliometric analysis and detailed overview. *Engineering Applications of Artificial Intelligence, 78*, 218–235. https://doi.org/10.1016/j.engappai.2018.11.007

Oakley, A. (2012). Foreword. In D. Gough, S. Oliver, & J. Thomas (Eds.), *An introduction to systematic reviews* (pp. vii–x). SAGE Publications. https://uk.sagepub.com/en-gb/eur/an-introduction-to-systematic-reviews/book245742

*Oberc, H., Prinz, C., Glogowski, P., Lemmerz, K., & Kuhlenkötter, B. (2019). Human robot interaction – learning how to integrate collaborative robots into manual assembly lines. *Procedia Manufacturing, 31*, 26–31. https://doi.org/10.1016/j.promfg.2019.03.005

OECD. (2019a). *Artificial intelligence in society.* OECD Publishing. https://doi.org/10.1787/eedfee77-en

OECD. (2019b). Scoping the OECD AI principles: Deliberations of the expert group on artificial intelligence at the OECD (AIGO). *OECD Digital Economy Papers, No. 291*. https://doi.org/10.1787/d62f618a-en

Pollitzer, E. (2019). Creating a better future: Four scenarios for how digital technologies could change the world. *Journal of International Affairs, 72*(1), 75–90. https://www.jstor.org/stable/26588344

Popenici, S. D., & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and Practice in Technology Enhanced Learning, 12*(22), 1–13. https://doi.org/10.1186/s41039-017-0062-8

Richardson, K. (2015). *An anthropology of robots and AI: Annihilation anxiety and machines.* Routledge.

Rizk, J. (2020). Considerations for implementing emerging technologies and innovative pedagogies in the 21st century. In S. Yu, M. Ally, & A. Tsinakos (Eds.), *Emerging technologies and pedagogies in the curriculum* (pp. 447–460). Springer.

Rosa, W. (Ed.). (2017). Transforming our world: The 2030 agenda for sustainable development. *In A new era in global health* (pp. 529-567). https://doi.org/10.1891/9780826190123.ap02

Rubin, A., & Brown, A. (2019). Unlocking the future of learning by redesigning educator learning. In J. W. Cook (Ed.), *Sustainability, human well-being, and the future of education* (pp. 235-268). Springer Nature. https://doi.org/10.1007/978-3-319-78580-6_7

Schwaninger, M. (2015). Organizing for sustainability: A cybernetic concept for sustainable renewal. *Kybernetes, 44*(6/7), 935–954. https://doi.org/10.1108/K-01-2015-0008

Smolenski, N. (2016). *Academic credentials in an era of digital decentralization.* https://www.academia.edu/29403234/Academic_Credentials_in_an_Era_of_Digital_Decentralization

*Stock, T., Obenaus, M., Kunz, S., & Kohl, H. (2018). Industry 4.0 as enabler for a sustainable development: A qualitative assessment of its ecological and social potential. *Process Safety and Environmental Protection, 118*, 254–267. https://doi.org/10.1016/j.psep.2018.06.026

The leapfrog model: What technology can do for Africa. (2017). *The Economist, 425*(9066), 5.

UNESCO. (2019a). Artificial intelligence in education: Challenges and opportunities for sustainable development. *Working Paper on Educational Development No. 7*. https://unesdoc.unesco.org/ark:/48223/pf0000366994

UNESCO. (2019b). *Meeting commitments: Are countries on track to achieve SDG4?* https://reliefweb.int/sites/reliefweb.int/files/resources/UNESCO-2019-HLPF_UIS_Meeting-EN-v7-web_aer.pdf

UNESCO Institute for Statistics. (2016). *The world needs almost 69 million new teachers to reach the 2030 education goals.* https://unesdoc.unesco.org/ark:/48223/pf0000246124

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development*. https://sustainabledevelopment.un.org/post2015/transformingourworld.

Vincent-Lancrin, S., & van der Vlies, R. (2020). Trustworthy artificial intelligence (AI) in education: Promises and challenges. *OECD Education Working Paper No. 218.* https://doi.org/10.1787/a6c90fa9-en

Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch S., Felländer, A., Simone Daniela Langhans, S. D., Tegmark, M., & Nerini F. F. (2020). The role of artificial intelligence in achieving the sustainable development goals. *Nature Communications, 11*, 1–10. https://doi.org/10.1038/s41467-019-14108-y

Visvizi, A. (2022). Artificial intelligence (AI) and sustainable development goals (SDGs): Exploring the Impact of AI on Politics and Society. *Sustainability, 14*(3), 1730. https://doi.org/10.3390/su14031730

*Wan Chik, W. N. A., & Arokiasamy, L. (2019). Perceived higher education climate of academics in Malaysian private institutions in Industry 4.0. *Global Business & Management Research, 11*(1), 488–504. http://www.gbmrjournal.com/pdf/vol.%2011%20no.%201/V11N1_2019.pdf

West, M., Kraut, R., & Chew, H. E. (2019*). I'd blush if I could: Closing gender divides in digital skills through education.* UNESCO Digital Library. https://unesdoc.unesco.org/ark:/48223/pf0000367416.page=7

World Economic Forum. (2017, January). *Realizing human potential in the Fourth Industrial Revolution: An agenda for leaders to shape the future of education, gender and work* [White paper]. http://www3.weforum.org/docs/WEF_EGW_Whitepaper.pdf

World Economic Forum. (2020). *Centre for the Fourth Industrial Revolution.* https://www.weforum.org/centre-for-the-fourth-industrial-revolution/

Wozniak, K. (2020). Personalized learning for adults: An emerging andragogy. In S. Yu, M. Ally, & A. Tsinakos (Eds.), *Emerging technologies and pedagogies in the curriculum* (pp. 185–198). Springer.

*Xue, L., Weng, L., & Yu, H. (2018). Addressing policy challenges in implementing sustainable development goals through an adaptive governance approach: A view from transitional China. *Sustainable Development, 26*(2), 150–158. https://doi.org/10.1002/sd.1726

*Zabidin, N. S., Belayutham, S., & Che Ibrahim, C. K. I. (2019). A bibliometric analysis of Industrial Revolution (IR) 4.0 in construction engineering education. *MATEC Web of Conferences, 266*, (Article number 05006). https://doi.org/10.1051/matecconf/201926605006

Authors

Mohamed Ally is Professor of Online and Distance Education at Athabasca University. His current areas of research include education in the fourth industrial revolution, mobile learning, online learning, distance education and use of emerging learning technologies in education. He is currently serving on three ISO committees to set international standards. Email: mohameda@athabascau.ca

Kirk Perris is a digital learning strategist who has worked internationally in formal and non-formal education sectors for 20 years. His interests lie in the implementation of virtual and blended learning interventions in institutional, national, and regional contexts. His focus areas are quality assurance, assessment, and workforce development. Email: kirkperris@gmail.com

CJLT RCAT

Canadian Journal of Learning and Technology
La Revue canadienne de l'apprentissage et de la technologie

Volume 48 (4) Special Issue 2022

Designing Knowledge Dissemination in a Digital Era – Analyzing TED Talks' Multimodal Orchestration

Concevoir la diffusion des connaissances à l'ère numérique- Analyse de l'orchestration multimodale de TED Talks

Jingxin Jiang*, Chongqing Open University, China; National Institute of Education, Nanyang Technological University, Singapore*

Fei Victor Lim*, National Institute of Education, Nanyang Technological University, Singapore*

Abstract

Online learning has gained increasing attention during the COVID-19 pandemic. Teachers face social exigencies to design ways of knowledge dissemination in online instruction. We posit that understanding how knowledge can be represented in successful online academic genres can inform teachers on how they can design students' online learning experiences. This study examined how scientific knowledge is disseminated in one of the most widespread academic genres, TED Talks, which share discoursal similarities with other academic genres such as online lectures. This study adopted a systemic functional multimodal discourse analysis approach to explore how a presenter used speech, images, and gestures to disseminate knowledge. The analysis shows that a presenter orchestrates speech, images, and gestures strategically to clarify the scientific ideas and engage the audience. Based on understanding how the three semiotic modes are used to disseminate scientific knowledge in accessible and engaging ways, this paper discusses how insights on multimodal orchestration can function as a heuristic tool to inform design in online learning.

Keywords: Online learning; TED Talks; Multimodal discourse analysis; Speech; Image; Gesture

Résumé

L'apprentissage en ligne a fait l'objet d'une attention croissante pendant la pandémie de COVID-19. Les enseignants sont confrontés à des exigences sociales pour concevoir des moyens de diffusion des connaissances dans l'enseignement en ligne. Nous postulons que la compréhension de la façon dont les connaissances peuvent être représentées dans des genres académiques en ligne réussis peut informer les enseignants sur la façon dont ils peuvent concevoir les expériences d'apprentissage en ligne des étudiants. Notre étude a examiné la manière dont les connaissances scientifiques sont diffusées dans l'un des genres académiques les plus répandus, les TED Talks, qui partagent des similitudes discursives avec d'autres genres académiques tels que les cours magistraux en ligne. Cette étude a adopté une approche systémique d'analyse fonctionnelle du discours multimodal pour explorer la manière dont un présentateur utilise la parole, les images et les gestes pour diffuser des connaissances. L'analyse montre qu'un présentateur orchestre la parole, les images et les gestes de manière stratégique afin de clarifier les idées scientifiques et d'impliquer le groupe. Sur la base de la compréhension de la façon dont les trois modes sémiotiques sont utilisés pour diffuser des connaissances scientifiques de manière accessible et engageante, cet article discute de la façon dont les idées sur l'orchestration multimodale peuvent fonctionner comme un outil heuristique pour informer la conception de l'apprentissage en ligne.

Mots-clés : apprentissage en ligne ; TED Talks ; analyse multimodale du discours ; discours ; image ; geste

Introduction

Advancement in digital technology and the prevalence of new media have led to a fundamental change in the education sector, with online learning and teaching now considered at the forefront of 21st century pedagogy (Ali, 2020; Miller et al., 2020). The outbreak of COVID-19 has propelled a massive transition from face-to-face classrooms to online learning systems around the world and has made online learning a new normal (Martin, 2021; Teo et al., 2021). However, the effectiveness of online learning in the pandemic is debatable (Adedoyin & Soykan, 2020; Hamid et al., 2020). For example, many students are dissatisfied with their online learning experiences (Maqableh & Alia, 2021) and report difficulties understanding the lecturers' instruction and materials (Allo, 2020). Meanwhile, teachers and instructors are also faced with challenges such as how to communicate their content in online instruction, how to keep students engaged in online learning, and how to use multimedia resources effectively (Oyedotun, 2020; Pei & Wu, 2019).

It has been widely accepted that students' learning experiences are more influenced by the design of instruction and materials than by the medium and technology deployed (Ally, 2008; Mayer, 2019). For online learning especially, one important factor to consider is what resources are available and how these resources can be used to make instruction more accessible and engaging (Niess, 2012; Shalev-Shwartz, 2011). Investigating how knowledge is represented in successful online academic genres can help teachers and instructors use the various semiotic modes afforded by online platforms to disseminate knowledge well. To this end, this study examined how scientific knowledge is disseminated multimodally in one of the most widespread academic genres, the TED Talks. We argue that given the discoursal similarities between TED Talks and online lectures, understanding the ways of multimodal orchestration can function as a heuristic tool to inform the design of knowledge dissemination in online learning.

TED is the acronym for technology, entertainment, and design. It is a non-profit organization that aims to spread inspired ideas and has gained centrality in disseminating scientific knowledge. It provides a platform for scientists and researchers from different disciplines to popularize their latest research, inventions, and creative ideas[1]. With their easy accessibility, TED Talks have long been used in teaching and learning and recognized as an academic genre (D'avanzo, 2015; Harrison, 2021). As a prestigious genre, TED Talks share discoursal similarities in knowledge representation with other academic genres such as academic oral presentations and lectures (Chang & Huang, 2015; Harrison, 2021). Thus, the delivery style and techniques can shed light on the designing of knowledge dissemination in online lectures and inform teachers and instructors how semiotic modes ("a socially organized set of semiotic resources for making meaning" such as image, speech, and gesture [Jewitt et al., 2016, p.157]) can be orchestrated in accessible and engaging ways in online learning. Taking one of the most popular TED Talks (based on number of views) as an illustrative example, this study adopted a systemic functional multimodal discourse analysis approach to explore how the presenter orchestrated different semiotic modes—speech, images on slides, and hand gestures—to achieve effective knowledge dissemination, and discuss how this can inform teachers' and instructors' design in online learning. In this paper, we use the terms *presenter* to indicate the speaker who delivers the TED Talk and *audience* to indicate the people who view the talks. While TED Talks are open to the public, most audience members are non-expert viewers, so they are often referred to as the lay audience or lay public. The term *participant* indicates the persons (or entities) who perform an action in the analysis of the meaning representation by the three modes.

[1] www. ted.com

Research Background

Online Learning

Online learning, also referred to as e-learning, digital learning, and computer-based learning, has been broadly defined as "instruction delivered on a digital device that is intended to support learning" (Mayer, 2019, p. 152). It involves using the Internet and digital technologies to access the learning materials and the instructional delivery to achieve effective learning (Adedoyin & Soykan, 2020; Ally, 2008). Online learning can be either synchronous or asynchronous. Synchronous online learning involves real-time engagement between the teacher and students in a virtual classroom. Asynchronous online learning is self-paced and students can access the prepared digital instructional materials and perform learning activities at their preferred time (Ogbonna et al., 2019). Both synchronous and asynchronous online learning involve teachers' use of different semiotic resources, like slides and gestures to accompany speech in an online lecture or videos in asynchronous learning.

Mayer (2002) and Mayer and Moreno (2002) developed the theory of multimedia learning which suggests that people's processing capacity of working memory is limited and, hence, it is important to reduce students' cognitive load when designing instructions (Bannert, 2002; Sweller, 2005). The cognitive theory of multimedia learning assumes that people have different apparatus in processing different semiotic modes (speech or images). Different semiotic modes can be used synchronically to disseminate knowledge. As processing capacity is limited in working memory, effective learning occurs when people are involved with appropriate cognitive processing, which necessitates the strategic orchestration of different semiotic modes when designing online instruction (Mayer, 2019).

TED Talks as an Academic Genre

A *genre* refers to a series of communicative events with common purposes agreed upon by a particular group of people (Swales, 1990). The aim of a genre is to realize its communicative intention with recognizable generic features within a community. Many genres are used for academic purposes, such as lectures, online courses, academic presentations, and science popularization. As an academic genre, TED Talks share rhetorical and discoursal features with other academic genres. For instance, the vocabulary representation, lexical density, and speech rate of TED Talks are similar to those in lectures (Wingrove, 2017). They also resemble university lectures in the use of words and multimedia resources to express a speaker's stance and avoid misunderstanding (D'avanzo, 2015; Mattiello, 2019). With the common communicative purpose of knowledge dissemination in an online medium, we argue that a discourse analysis of TED Talks can inform the ways online learning can be designed.

Presentations are also a common way to disseminate knowledge in academic genres, such as seminars, lectures, and classroom teaching (Tardy, 2005). Because of their easy accessibility, TED Talks have been used as models of effective communication. For instance, in Li et al. (2016), TED Talks were used to teach the organization of ideas in oral presentations and were reported to be effective in enhancing students' thinking ability and presentation skills. In Salem (2019), TED Talks were used as model presentations in a business English presentation course, and students' presentation skills improved. TED Talks are thus a useful resource for teaching the design of oral presentations in physical classrooms. In the same way, TED Talks can be useful in online instruction, which has similar purposes and audience. We posit that the findings from the multimodal analysis of TED Talks can also illuminate the ways different semiotic modes can be used in online instruction, such as the representation of ideas in a presentation during synchronous online learning and a recorded video presentation as material for asynchronous online learning.

Use of Multimodality in Knowledge Dissemination

One commonality shared between TED Talks and other academic genres is the crucial role of multimodality to disseminate knowledge (Jewitt et al., 2016). Previous studies have found that images (including photos, tables, and scripts) play an essential role in representing scientific knowledge (Tardy, 2005) and can help an audience get a better understanding of texts (Bucchi & Saracino, 2016; Rowley-Jolivet, 2012). There are also many studies investigating the use of gestures in face-to-face classroom teaching. For example, Alibali et al. (2014) examined teacher's gestures in middle school mathematics classes and claimed that "gestures are an integral part of teachers' communication during mathematics instruction" (p. 65). Chue et al. (2015) investigated the functions of gestures in teaching chemistry. They found that iconic gestures can help illustrate abstract ideas and present a more complete version of meaning than when represented by speech alone.

Previous Studies on the Multimodal Nature of TED Talks

The multimodal nature of TED Talks has been described in previous studies (Harrison, 2021; Masi, 2016, 2020). By analyzing the synchronization of gestures and speech, Masi (2016, 2020) observed that hand gestures are often used to reinforce meaning in abstract concepts and promote audience involvement. Harrison (2021) investigated the speech-gesture-slide interplay in two sample talks through the lens of showing as sense-making and found that the orchestration of the three modes helped the audience make sense of images on slides, understand, and remain engaged in the talk. However, the multimodal orchestration involved the interaction and interplay across semiotic modes and warrants further examination. In this study, we analyzed the orchestration of speech, images, and hand gestures to describe the interplay and discuss how the orchestration can inform design in online learning. We addressed these research questions:

1. How does the presenter use speech, images, and gestures to disseminate scientific knowledge in the TED Talk?
2. How can the analysis of TED Talks serve as a heuristic to inform the design of knowledge dissemination in online learning?

Methods

A Systemic Functional Multimodal Discourse Analysis Approach

From the multimodal perspective, different semiotic modes have different sets of rhetorical devices and could be understood in their design and functions (Harrison, 2003). In systemic functional theory, language, in speech or writing, is regarded as a semiotic mode and a resource for meaning-making (Halliday, 1994). Language makes meanings in combination with other semiotic modes to form an integrated whole. This understanding is aligned with the interconnected cognitive processing in different channels in the cognitive theory of multimedia learning (Mayer, 2002). The systemic functional multimodal discourse analysis approach (SF-MDA) (O'Halloran, 2008) was adopted in the present study. SF-MDA aims to understand and describe the functions of different semiotic modes as systems of meaning and the emergent meanings arising in the orchestration of these modes (Jewitt et al., 2016).

Framework to Annotate Speech

Semiotic modes serve the ideational metafunction to represent ideas and experiences, the interpersonal metafunction to enact social relation, and the textual metafunction to organize the discourse (Halliday, 1994). Systemic functional grammar (SFG) was adopted to annotate speech. In SFG, the ideational meanings are realized by the system of transitivity, which describes the type of action process that the participant conducts in a clause. Interpersonal meanings are realized by a system of mood block, mood types, and modality. Mood block includes two parts: the subject and the finite. The persons or entities who carry out the social practices (exchange of information or goods/service) are known as the subject, and the transaction's validity is described by the term finite. The verb used in exchanging information or goods/services is described by mood types, comprising declarative, interrogative, indicative, and imperative moods. Another indicator, modality, describes the extent of probability, usuality, obligation, and inclination. Textual meanings are realized by the system of theme (the first constituent of a clause) and rheme (the remaining part of the clause), which indicates the first element of a clause, serving to examine the organization of a text.

Framework to Annotate Images

In images, ideational meanings are realized by representational structures, i.e., the relationship between participants in an image and the nature of the actions. Interpersonal meanings, in terms of "symbolic contact, social distance, power relations, and involvement between viewers and visual participants" (Feng & O'Halloran, 2013), are realized by how participants gaze at viewers, the shot distance (long, medium, or close), vertical camera angles (high, eye-level, or low), and horizontal camera angles (frontal or oblique), respectively. Textual meaning is expressed in the composition and layout of the image through three systems: information value, salience, and framing. Information value is viewed through the layout and placement (i.e., top and bottom, left and right, centre and margin), salience through the prominence and importance of visual elements, and framing through the connection and disconnection between visual components.

Framework to Annotate Gestures

Gestures were annotated according to Martinec's (2000) scheme for classifying actions, including presenting action, representing action, and indexical action. Presenting actions indicate gestures that do not represent meaning, such as holding the hands in front of the body. Representing action has a conventional signifying function, which can express meaning. Based on the relationship between gesture and language, Lim (2019) classified representing action into two categories: language correspondent gestures and language independent gestures. Indexical action often occurs with speech and should be interpreted in synchronization with the utterances (Martinec, 2000). It is also described as language correspondent gesture (Lim, 2019). The ideational meanings of presenting actions, such as those in SFG, are realized through transitivity processes such as the material, behavioural, state, verbal, and mental processes. To describe the ideational meaning of representing actions, congruent entities (i.e., participants, processes, or circumstances) and metaphorical concepts are examined. Indexical actions are considered through importance, receptivity, and relation. The interpersonal meanings of gestures are annotated through dimensions of attitude (positive, negative, and neutral), engagement (expansion, contraction, neutral, and possibility), and graduation (fast, medium, and slow). Textual meanings in gestures are examined through wavelength (size and rhythm) and pointing (directionality and specificity).

How Orchestration Across Speech, Images, and Gestures Was Annotated

The orchestration of speech, images, and gestures was examined through the ways they interplayed and functioned. Informed by O'Halloran's (2008) framework in the study of text-image interplay and Lim's (2021) description of verbal-gestural interrelations, the presenter's orchestration of the three modes was annotated according to their meaning convergence and divergence. The interplay across semiotic modes can work together to express congruent meanings through convergence and different or even contradictory meanings through divergence (O'Halloran, 2008, p. 90).

The Data

This study is part of a larger research project which focuses on multimodal analysis of TED Talks. The video analyzed was downloaded from the TED website (https://www.ted.com). The talks on this website are classified using categories such as "topic," "the most viewed," and "the latest." The talk under analysis is social psychologist Amy Cuddy's (2012) talk: *Your Body Language May Shape Who You Are* (https://www.ted.com/talks/amy_cuddy_your_body_language_may_shape_who_you_are). It explains how body language changes people's behaviour and consequently changes their life. It appears on the home page in the playlist "The most popular talks of all time," with 63,730,150 views (7 January 2022) and can be considered representative of the TED Talks genre. It is also popular among viewers, suggesting interest and indicating that the talk is successful. Transcripts were annotated clause by clause, images slide by slide, and gestures action by action.

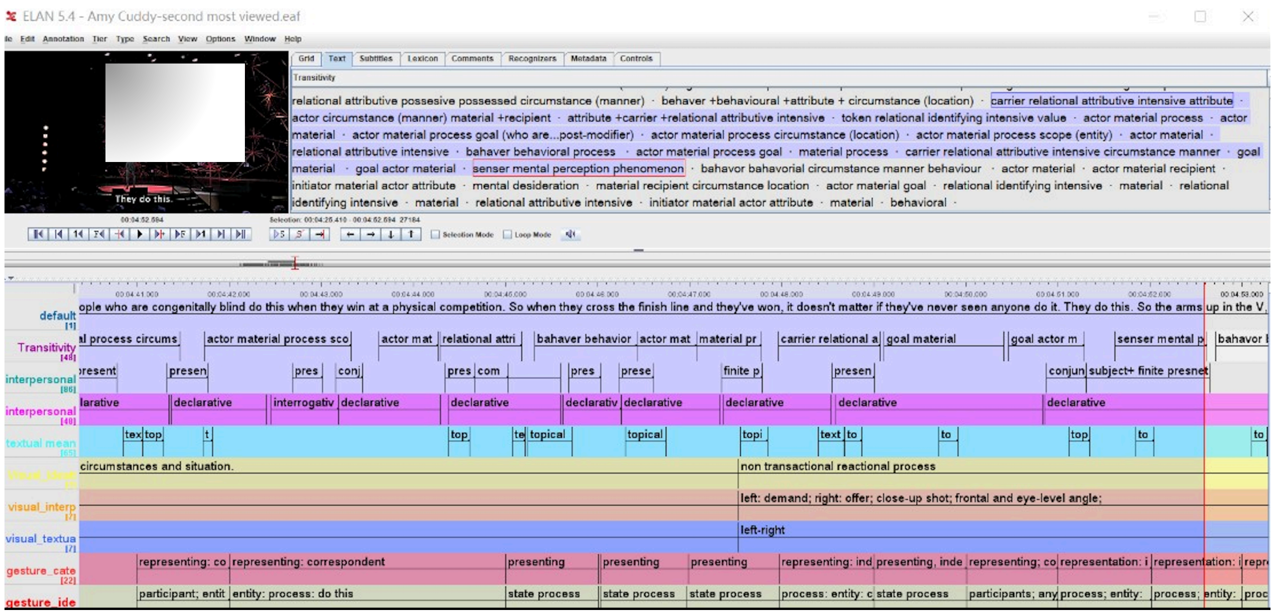
Data Analysis

In the study, we performed a detailed annotation of the data, with iterative viewing and zooming into instances of multimodal orchestration. Clauses of the transcripts and screenshots of special moments were extracted for fine-grained analysis and detailed description. Reproduction of screenshots in this paper is supported by the TED Talks Usage Policy and licensed under a Creative Commons license (CC BY–NC–ND 4.0 International [https://www.ted.com/about/our-organization/our-policies-terms/ted-talks-usage-policy]).

ELAN (Version 5.4) was used for the analysis (Figure 1). It provides functions, such as time-aligned annotation, fragmentation, and labelling. It is organized in tiers and is hierarchically interconnected, allowing exploration of the annotation's interplay on each tier (https://tla.mpi.nl/tools/tla-tools/elan/elan-description/). Documentation and search functions also aid in the iterative reading of data and identifying characteristics, as well as locating and capturing a screengrab at an interesting moment.

Figure 1

Screenshot of ELAN



Note. The image is a screenshot of ELAN (V.5.4)[Computer software]. (2018). Nijmegen: Max Planck Institute for Psycholinguistics, The Language Archive. https://archive.mpi.nl/tla/elan/

Findings

Our first research question focused on how the presenter used speech, images, and gestures to disseminate scientific knowledge in this TED Talk. TED Talks aim to spread science to a lay audience, making it necessary to represent sophisticated scientific ideas in an accessible way. Meanwhile, like other online academic genres, such as science news and online courses, TED Talks have long competed for an audience's attention (Lorés, 2020). Most of the online audience bears a "scan and go" attitude (Zhang et al., 2015, p. 239), though it is vital to keep the audience involved. Thus, the presenter must orchestrate speech, images, and gestures effectively. In what follows, we describe the meanings made in the three modes, analyze their interplay, and interpret how multimodal orchestration contributes to the effective dissemination of scientific knowledge in the focal TED talk.

Use of Speech, Images, and Gestures to Clarify Meaning

In terms of speech, it can be seen from the annotation that the presenter used a large amount of material process in transitivity, that is, the process involving physical actions to explain concepts, describe phenomena or observations, and report results and findings. For example, between 5:07 and 6:03 of the video clip, the presenter claimed that when we are in class and encounter a person using high-power gestures, we tend to make low-power gestures. She first described a series of actions that students of high power perform in the material process: “they get right into the middle of the room,” and “they raise their hands like this.” Then she discussed students’ low-power gestures, such as “they sit in their chairs, and they make themselves tiny.” The use of material process to describe specific actions can instantiate abstract concepts and vivify the description of phenomena or statements, and therefore help clarify ideas and facilitate audience understanding.

Correspondingly, images were displayed to support the meanings made in the speech. For example, to explain the concept of nonverbal expressions of power and dominance (3:48–5:09), the presenter deployed a series of images with participants performing a specific expanding or shrinking action. She first put forward the question of “What are nonverbal expressions of power and dominance?” to raise curiosity and appeal to the audience’s interest. In what followed, she answered this question using a guiding statement, “Well, this is what they are,” with a series of images (Figures 2 and 3). In most of these images, the participants’ gaze is directed away from the audience, forming a non-transactional reactional process, which allows the audience to focus on the actions displayed instead of participating in the event. While describing the images and elaborating the concept, the presenter used the two modes to form a meaning convergence. For instance, the presenter displayed an image (Figure 4) of a participant (the winner) in a running race. The winner is crossing the finish line while expanding his arms high in the air, forming the letter V. Combined with a detailed description of “the arms up in the V, the chin is slightly lifted,” the meaning of “non-verbal expression of pride” was vividly conveyed to the audience. The orchestration of the two modes clarified the concept, helped ease the burden in cognitive processing, and enhanced the intake of information and understanding of the content.

Figure 2

Access the Image of Participants with Expanding Gestures through: https://www.ted.com/talks/amy_cuddy_your_body_language_may_shape_who_you_are at 4:01-4:09

Note. This image presents two gorillas. One gorilla is holding its two arms high up in the air, the other is standing with arms akimbo. The transcript reads, “So in the animal kingdom, they are about expanding. So you make yourself big, you stretch out, you take up space.” In the public domain. (Cuddy, 2012).

Figure 3

Access the Image of Participants with Contrasting Gestures through: https://www.ted.com/talks/amy_cuddy_your_body_language_may_shape_who_you_are at 5:10-5:19

Note. This image presents two people. The lady is standing with arms akimbo, and the man is standing with two hands together in front of the body. The transcript reads, “And this is what happens when you put together high and low power. So, what we tend to do when it comes to power is that we complement the other’s nonverbals.” In the public domain. (Cuddy, 2012).

Meanwhile, when speech and gestures were exhibited in the video, hand actions were also used to disambiguate meaning. The language independent actions were mostly used to exemplify abstract concepts and make statements. When explaining the concepts, the presenter performed corresponding gestures, such as expanding (Figure 5) to demonstrate high power status and wrapping two arms in front of the chest (Figure 6) to show a lower power status. These gestures, in themselves, could express meanings of power and timidity. The meanings represented in the gestures concurred with those made in the speech: “really power” and “make ourselves small.” Thus, speech and gestures converged to form a whole and reinforce the meaning reciprocally in the two modes. In this way, the use of gestures allowed the audience to visualize and experience the specific and vivid “non-verbal expressions of power and dominance” expressed in the speech and enhanced the audience’s understanding of these concepts.

Figure 4

Access the Image of a Winner in a Running Race through:

https://www.ted.com/talks/amy_cuddy_your_body_language_may_shape_who_you_are at 4:53- 4:57

Note. This image presents a running race. The athlete is rushing through the finish line with two arms high up in the air. The transcript reads, “So the arms up in the V, the chin is slightly lifted.” In the public domain. (Cuddy, 2012).

Figure 5

Access the Screenshot When the Speaker Performed an Expanding Action through: https://www.ted.com/talks/amy_cuddy_your_body_language_may_shape_who_you_are at 5:12-5:13

Note. The screenshot presents the presenter and the screen in the background. The presenter performs a gesture of high power: expanding the two arms in a horizontal position with her shoulder. The transcript reads, “So if someone is being really powerful with us.” In the public domain. (Cuddy, 2012).

At times, the three modes converged to clarify the message in the video. For example, in Figure 7, the image displays gestures of powerless status where participants are seated with lowered heads and shrinking bodies. Meanwhile, the presenter was acting out a similar gesture, hunching up, with the verbal description, “You’re hunching up, making yourself small.” At this moment, the meanings represented in the three modes were in convergence, and the audience could process the information through different channels synchronically. The meanings were parallel and worked together as a whole, reinforcing the ideas. In this way, the audience could hear, visualize, and experience the statement through the repeated representation in the three modes, thus facilitating the lay audience to understand the ideas.

Figure 6

Access the Screenshot When the Speaker Hunched Shoulders and Crossed Arms through: https://www.ted.com/talks/amy_cuddy_your_body_language_may_shape_who_you_are at 5:14-5:15

Note. This screenshot shows the presenter and the screen at the background. She performs a shrinking gesture with two arms wrapping herself. The transcript reads, “We tend to make ourselves smaller.” In the public domain. (Cuddy, 2012).

The three modes can also supplement one another in meaning. Figure 8 shows such an interplay. At this moment, the speaker was describing a job interview and stating that “for numerous reasons, no, no, no, don’t do that,” with two hands beating downward to emphasize the “do that.” While the speech and gestures were semantically parallel in their expression of the meaning in the action process, it was still unclear what “that” indicated. However, the image on the screen in the background supplemented the other modes and illustrated the meaning of “that” (hands high up in a V shape and feet on the desk). Thus, in this kind of interplay, the image has supplemented the meaning constructed by spoken and gestural instances and, consequently, the presenter achieved clarity and disambiguation of the meaning. Converging the three modes in the way of supplementation clarifies the meaning represented, eases the burden of comprehension, and improves the accessibility of this talk.

Figure 7

Access the Screenshot of an Orchestration of the Three Modes in Convergence (Concurrence) through: https://www.ted.com/talks/amy_cuddy_your_body_language_may_shape_who_you_are at 13:46

Note. The screenshot shows the whole platform with a slide in the background. The presenter is standing with her two arms wrapping herself. The image in the background presents three people who are sitting with their heads down. The orchestration happens at 13:46. The transcript reads, “You’re hunching up, making yourself small.” In the public domain. (Cuddy, 2012).

Figure 8

Access the Screenshot of Orchestration of the Three Modes in Convergence (Supplementation) through: https://www.ted.com/talks/amy_cuddy_your_body_language_may_shape_who_you_are at 13:28

Note. The screenshot presents the speaker and the image in the background. The speaker is moving her hands in a upward and downward in a beating down motion. The image in the background shows an interviewee with her two arms high and legs on the desk. The orchestration happens at 13:28. The transcript reads, “For numerous reasons, no, no, no, don’t do that.” In the public domain. (Cuddy, 2012).

According to Valeiras-Jurado et al. (2018), the more easily a message is understood, the more accessible and persuasive it comes to be. Only when an idea is clearly conveyed and easily understood can it be accessed, accepted, and disseminated. Hence, it is of utmost importance to make ideas clear to persuade the audience. Moreover, it may be difficult for lay audiences to comprehend sophisticated scientific concepts, terminologies, rationales, and statements in a specific field. Thus, making reference to specific objects, actions, or concrete examples, represented by the three modes coherently, could help an audience visualize abstract ideas and enhance their comprehension.

Use of Speech, Images, and Gestures to Engage an Audience

The presenter appeared to make certain choices of image and gesture in order to appeal to the audience. The interpersonal meanings made in the images selected for this talk helped engage the audience. According to Kress and Van Leeuwen (2006), a medium close-up shot and eye-level frontal angle can enact a sense of intimacy with an audience (Figures 2, 3, and 4). The participants’ actions of spreading out or shrinking represented in these images are relatable to the daily experiences of the audience and thus created familiarity and enhanced engagement.

Gestures also enhance audience involvement. Indexical actions that occur with speech would necessarily require speech for interpretation (Lim, 2019). Although less frequently used, the indexical action of pointing is observed in this talk (Figures 9 and 10). In the process of asking the question, “So what is your body language communicating to me?”, the presenter pointed to the audience when she said “you” and to herself when she said “me.” The action of pointing with the personal pronouns heightened the sense of invitation and participation, thus building a sense of involvement. This helps bring about stronger audience engagement.

It was also found that the three modes were used in deviation or contradiction to one another in order to involve the audience. Figure 11 illustrates this orchestration. Between 13:17 and 14:40, the presenter described an experiment of an interview, aiming to test whether the practice of high-power gestures could change people's lives in the real world. The screenshot is from 13:29, when the presenter described an imagined scenario that contradicts people's conventional expectations and showed the image of an interviewee expanding arms and legs. Meanwhile, she joked, "Okay, so this is what you do when you go in for the job interview, right?" In this orchestration, the participant's gesture displayed in the image complemented what "this" indicates.

Figure 9

Access the Screenshot of Indexical Action Converged with Speech #1 through: https://www.ted.com/talks/amy_cuddy_your_body_language_may_shape_who_you_are at 2:00

Note. The screenshot shows the presenter pointing downward with her index finger. The orchestration happens at 2:00. The transcript reads, "So what is your body language…" In the public domain. (Cuddy, 2012).

Figure 10

Access the Screenshot of Indexical Action Converged with Speech #2 through: https://www.ted.com/talks/amy_cuddy_your_body_language_may_shape_who_you_are at 2:02

Note. The screenshot shows the presenter pointing herself with two hands. The orchestration happens at 2:02. The transcript reads, "…communicating to me?" In the public domain. (Cuddy, 2012).

However, the gesture was of a state process and did not carry ideational meaning, and thus was disparate from the meanings represented in the images and speech. The three modes did not represent meanings congruently. In other words, they were in meaning divergence. Although the presenter's gesture could not add ideational meaning to what the speech and the images represented, the relaxed state of hand gesture, combined with the ideational meaning that contradicted people's expectation created a relaxed atmosphere by using humour to keep the audience involved.

Figure 11

Access the Screenshot of Orchestration of the Three Modes in Divergence through: https://www.ted.com/talks/amy_cuddy_your_body_language_may_shape_who_you_are at 13:29

Note. In this screenshot, the presenter is standing with two hands in front of her body. The image shown in the background is an interviewee with hands and legs fully expanding. The orchestration happens at

13:29. The transcript reads, “Okay, so this is what you do when you go in for the job interview, right?” In the public domain. (Cuddy, 2012).

In an online academic genre, it is critical to maintain engagement between presenter and audience. The interpersonal meanings expressed by the medium close-up shot of the stage with a frontal eye-level angle helped to enact a sense of familiarity and involvement. The indexical actions with corresponding spoken utterances also created a feeling of dialogue and participation. In addition, the instances where the three modes represented incongruent meanings in divergence created a relaxed atmosphere and humour. Thus, the image and gesture instances as well as the artful orchestration of meaning divergence contributed to enacting a sense of participation and enhancing audience engagement.

Discussion

Analysis of the TED Talk reveals the ways in which the speaker used speech, images, and gestures strategically to disseminate scientific knowledge in accessible and engaging ways by clarifying ideas and engaging the audience. Many linguistic choices, for example, material process and declarative, were used to represent scientific knowledge in a direct manner. Converging with speech, images, and gestures worked in combination to explain abstract concepts, reinforce key statements, and form a meaning whole. This could have eased the burden of cognitive processing and enhanced the audience’s understanding. Meanwhile, a medium close-up shot from frontal and eye-level angles was deployed to enact a sense of involvement. Indexical actions combined with pronouns in speech created a sense of belonging and facilitated the presenter’s engagement with the audience. The three modes also worked in divergence to express humour which kept the audience involved.

We posit that the findings from this analysis can inform teachers’ design of online learning to address the currently reported challenges, such as difficulties in students’ understanding of online instruction and materials (Allo, 2020). According to Mayer (2002), people’s processing capacity is limited in the working memory, and only appropriate cognitive processing can bring about learning. As such, a teacher’s intentional use of semiotic modes can clarify meaning in online teaching and reduce unnecessary cognitive load on students and facilitate learning. For example, a teacher can use gestures and images to vivify the description made in speech. Gestures and images can also be used to illustrate abstract concepts expressed in teachers’ speech through meaning convergence. As observed in the analysis of the TED Talk, orchestration across semiotic modes can ease the burden on cognitive processing and enhance the intake of information and the understanding of content. When a teacher uses the three semiotic modes to supplement one another, the interplay can clarify meaning, ease the burden of comprehension, and improve the accessibility of ideas being disseminated (Valeiras-Jurado et al., 2018). This, we argue, is superior to the sole use of language, whether a teacher's speech or words on a slideshow presentation, to disseminate knowledge in online teaching.

Another challenge related to online learning is the need to keep the students engaged (Oyedotun, 2020). We argue that the artful orchestration of the semiotic modes of speech, images, and gestures can serve to better engage students during online instruction. When the modes are used to express meaning divergence, where each mode seems to express contradictory meaning, students' interest could be piqued and attention drawn. For example, a teacher could use speech and gestures to express seemingly oppositional meanings to create humour. Such playful orchestration of semiotic modes to express meaning divergence contributes to a structured informality which builds solidarity and rapport between the teacher and students, creates a convivial learning environment, and encourages student engagement (Lim, 2021).

With greater semiotic awareness (Towndrow et al., 2013), teachers can design online learning experiences that disseminate knowledge in an accessible and engaging manner. Teachers, as designers of learning experiences, can apply semiotic awareness for orchestration of their speech, images, and gestures in embodied teaching (Lim, 2020). A more intentional use of semiotic modes in online instruction can mitigate the challenges of not being able to meet and interact with students in the physical classroom (Tanis, 2020). Online learning cannot be a substitute for face-to-face. Online learning offers new ways of learning and when designed well, it can be superior (Kalantzis & Cope, 2020). In this paper, we argue that the design of online learning begins with a more intentional orchestration of the teacher's speech, gestures, and images to disseminate knowledge in accessible and engaging ways.

Conclusion

This study has discussed how an understanding of the use of speech, images, and gestures to disseminate scientific ideas in TED Talks can inform the design of online instruction. Using one of the most viewed videos as an illustrative example, the fine-grained analysis has described the interplay across the three modes, revealed the ways of strategic orchestration, and demonstrated how they functioned to clarify the ideas and achieve audience engagement. TED Talks and online instruction have in common a communicative purpose of knowledge dissemination. They also share the online medium and seek to engage non-expert audiences. As such, an understanding of how the presenter orchestrates speech, images, and gestures in TED Talks can also illuminate the ways knowledge can be delivered in online instruction. Based on understanding how the three semiotic modes are used to disseminate scientific knowledge in accessible and engaging ways, our paper argues that insights into multimodal orchestration can function as a heuristic tool to inform the design of knowledge dissemination in online learning.

While the present analysis is based on one popular TED Talk, we seek to demonstrate how any similar fine-grained analysis can reveal the strategic use of multimodal orchestration to fulfill the communicative purposes of TED Talks and to draw illustrative applications for online lectures. Further study on a larger database of TED Talks may be pursued. Future research could also be conducted on TED Talk video production, considering choices such as camera angles and post-production editing. As our paper focuses on online learning, we have not discussed how the ways of multimodal orchestration in TED talks could also inform the design of face-to-face learning, which could also be a subject for future research.

Acknowledgement

This study was supported by Nanyang Technological University Research Scholarship. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the university.

References

Adedoyin, O. B., & Soykan, E. (2020). Covid-19 pandemic and online learning: The challenges and opportunities. *Interactive Learning Environments*. Advance online publication. 1-13. https://doi.org/10.1080/10494820.2020.1813180

Ali, W. (2020). Online and remote learning in higher education institutes: A necessity in light of COVID-19 pandemic. *Higher Education Studies*, *10*(3), 16-25. https://doi.org/10.5539/hes.v10n3p16

Alibali, M. W., Nathan, M. J., Wolfgram, M. S., Church, R. B., Jacobs, S. A., Johnson Martinez, C., & Knuth, E. J. (2014). How teachers link ideas in mathematics instruction using speech and gesture: A corpus analysis. *Cognition and Instruction*, *32*(1), 65-100. http://dx.doi.org/10.1080/07370008.2013.858161

Allo, M. D. G. (2020). Is the online learning good in the midst of Covid-19 pandemic? The case of EFL learners. *Jurnal Sinestesia*, *10*(1), 1-10. https://sinestesia.pustaka.my.id/journal/article/view/24

Ally, M. (2008). Foundations of educational theory for online learning. In T. Anderson & F. Elloumi (Eds.), *Theory and practice of online learning* (pp. 3-31). Athabasca University Press.

Bannert, M. (2002). Managing cognitive load—Recent trends in cognitive load theory. *Learning and Instruction*, *12*(1), 139-146. https://psycnet.apa.org/doi/10.1016/S0959-4752(01)00021-4

Bucchi, M., & Saracino, B. (2016). "Visual Science Literacy" images and public understanding of science in the digital age. *Science Communication*, *38*(6), 812-819. https://doi.org/10.1177/1075547016677833

Chang, Y.-J., & Huang, H.-T. (2015). Exploring TED Talks as a pedagogical resource for oral presentations: A corpus-based move analysis. *English Teaching & Learning*, *39*(4), 29-62. http://dx.doi.org/10.6330/ETL.2015.39.4.02

Chue, S., Lee, Y.-J., & Tan, K. C. D. (2015). Iconic gestures as undervalued representations during science teaching. *Cogent Education*, *2*(1), Article 1021554. https://doi.org/10.1080/2331186X.2015.1021554

Cuddy, A. (2012, June). Your body language may shape who you are [Video]. TED Conferences.

https://www.ted.com/talks/amy_cuddy_your_body_language_may_shape_who_you_are

D'avanzo, S. (2015). Speaker identity vs. speaker diversity: The case of TED Talks corpus. In G. Balirano & M. C. Nisco (Eds.), *Languaging diversity: Identities, genres, discourses* (pp. 279-296). Cambridge Scholars Publishing.

ELAN (Version 5.4)[Computer software]. (2018). Nijmegen: Max Planck Institute for Psycholinguistics, The Language Archive. https://archive.mpi.nl/tla/elan/

Feng, D., & O'Halloran, K. L. (2013). The visual representation of metaphor: A social semiotic approach. *Review of Cognitive Linguistics. Published under the auspices of the Spanish Cognitive Linguistics Association*, *11*(2), 320-335. https://doi.org/10.1075/rcl.11.2.07fen

Halliday, M. A. K. (1994). *An introduction to functional grammar* (2nd ed.). Edward Arnold.

Hamid, R., Sentryo, I., & Hasan, S. (2020). Online learning and its problems in the Covid-19 emergency period. *Jurnal Prima Edukasia*, *8*(1), 86-95. https://doi.org/10.21831/jpe.v8i1.32165

Harrison, C. (2003). Visual social semiotics: Understanding how still images make meaning. *Technical Communication*, *50*(1), 46-60.

Harrison, S. (2021). Showing as sense-making in oral presentations: The speech-gesture-slide interplay in TED Talks by Professor Brian Cox. *Journal of English for Academic Purposes*, Article 101002. https://doi.org/10.1016/j.jeap.2021.101002

Jewitt, C., Bezemer, J., & O'Halloran, K. (2016). *Introducing multimodality*. Routledge.

Kalantzis, M., & Cope, B. (2020). After the COVID-19 crisis: Why higher education may (and perhaps should) never be the same. *Access: Contemporary Issues in Education*, *40*(1), 51-55. https://doi.org/10.46786/ac20.9496

Kress, G., & van Leeuwen, T. (2006). *Reading images: The grammar of visual design* (2nd ed.). Routledge.

Li, Y., Gao, Y., & Zhang, D. (2016). To speak like a TED speaker—A case study of TED motivated English public speaking study in EFL teaching. *Higher Education Studies*, *6*(1), 53-59. https://doi.org/10.5539/HES.V6N1P53

Lim, F. V. (2019). Analysing the teachers' use of gestures in the classroom: A systemic functional multimodal discourse analysis approach. *Social Semiotics*, *29*(1), 83-111. https://doi.org/10.1080%2F10350330.2017.1412168

Lim, F. V. (2020). *Designing learning with embodied teaching: Perspectives from multimodality*. Routledge.

Lim, F. V. (2021). Investigating intersemiosis: A systemic functional multimodal discourse analysis of the relationship between language and gesture in classroom discourse. *Visual Communication*, *20*(1), 34-58. https://doi.org/10.1177/1470357218820695

Lorés, R. (2020). Science on the web: The exploration of European research websites of energy-related projects as digital genres for the promotion of values. *Discourse, Context & Media*, *35*, Article 100389. https://doi.org/10.1016/j.dcm.2020.100389

Maqableh, M., & Alia, M. (2021). Evaluation online learning of undergraduate students under lockdown amidst COVID-19 Pandemic: The online learning experience and students' satisfaction. *Children and Youth Services Review*, *128*, Article 106160. https://doi.org/10.1016/j.childyouth.2021.106160

Martin, B. A. (2021). Teachers perceptions of Google Classroom: Revealing urgency for teacher professional learning. *Canadian Journal of Learning and Technology*, *47*(1). https://doi.org/10.21432/cjlt27873

Martinec, R. (2000). Construction of identity in Michael Jackson's Jam. *Social Semiotics*, *10*(3), 313-329. https://doi.org/10.1080/10350330050136370

Masi, S. (2016). Gestures in motion in TED Talks: Towards multimodal literacy. In V. Bonsignori & B. C. Camiciottoli (Eds.), *Multimodality Across Communicative Settings, Discourse Domains and Genres* (pp. 146-165). Cambridge Scholars Publishing.

Masi, S. (2020). Exploring meaning-making practices via co-speech gestures in TED Talks. *Journal of Visual Literacy*, *39*(3-4), 201-219. https://doi.org/10.1080/1051144X.2020.1826223

Mattiello, E. (2019). A corpus-based analysis of scientific TED Talks: Explaining cancer-related topics to non-experts. *Discourse, Context & Media*, *28*, 60-68. http://dx.doi.org/10.1016/j.dcm.2018.09.004

Mayer, R. E. (2002). Multimedia learning. *Psychology of Learning and Motivation*, *41*, 85-139. https://doi.org/10.1016/S0079-7421(02)80005-6

Mayer, R. E. (2019). Thirty years of research on online learning. *Applied Cognitive Psychology*, *33*(2), 152-159. https://doi.org/10.1002/acp.3482

Mayer, R. E., & Moreno, R. (2002). Aids to computer-based multimedia learning. *Learning and Instruction*, *12*(1), 107-119. http://dx.doi.org/10.1016/S0959-4752(01)00018-4

Miller, T., MacLaren, K., & Xu, H. (2020). Online learning: Practices, perceptions, and technology. *Canadian Journal of Learning and Technology/La revue canadienne de l'apprentissage et de la technologie*, *46*(1). https://doi.org/10.21432/cjlt27894

Niess, M. L. (2012). Teacher knowledge for teaching with technology: A TPACK lens. In R. N. Ronau, C. R. Rakes, & L. N. Margaret (Eds.), *Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches* (pp. 1-15). IGI Global. https://doi.org/10.4018/978-1-60960-750-0.ch001

Ogbonna, C. G., Ibezim, N. E., & Obi, C. A. (2019). Synchronous versus asynchronous e-learning in teaching word processing: An experimental approach. *South African Journal of Education*, *39*(2), 1-15. https://doi.org/10.15700/saje.v39n2a1383

O'Halloran, K. L. (2008). Systemic functional-multimodal discourse analysis (SF-MDA): Constructing ideational meaning using language and visual imagery. *Visual Communication*, *7*(4), 443-475. https://doi.org/10.1177/1470357208096210

Oyedotun, T. D. (2020). Sudden change of pedagogy in education driven by COVID-19: Perspectives and evaluation from a developing country. *Research in Globalization*, *2*, Article 100029. https://doi.org/10.1016/j.resglo.2020.100029

Pei, L., & Wu, H. (2019). Does online learning work better than offline learning in undergraduate medical education? A systematic review and meta-analysis. *Medical Education Online*, *24*(1), Article 1666538. https:// doi.org/10.1080/10872981.2019.1666538

Rowley-Jolivet, E. (2012). Oralising text slides in scientific conference presentations: A multimodal corpus analysis. In A. Boulton, S. Carter-Thomas, & E. Rowley-Jolivet (Eds.), *Corpus-informed research and learning in ESP* (pp. 135-166). John Benjamins.

Salem, A. A. (2019). A sage on a stage, to express and impress: TED Talks for improving oral presentation skills, vocabulary retention and its impact on reducing speaking anxiety in ESP settings. *English Language Teaching*, *12*(6), 146-160. https://doi.org/10.5539/ELT.V12N6P146

Shalev-Shwartz, S. (2011). Online learning and online convex optimization. *Foundations and Trends in Machine Learning*, *4*(2), 107-194. https://doi.org/10.1561/2200000018

Swales, J. (1990). *Genre analysis: English in academic and research settings*. Cambridge University Press.

Sweller, J. (2005). Implications of cognitive load theory for multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 19-30). Cambridge University Press. https://doi.org/10.1017/CBO9780511816819.003

Tanis, C. J. (2020). The seven principles of online learning: Feedback from faculty and alumni on its importance for teaching and learning. *Research in Learning Technology*, *28*, Article 2319. https://doi.org/10.25304/rlt.v28.2319

Tardy, C. M. (2005). Expressions of disciplinarity and individuality in a multimodal genre. *Computers and Composition*, *22*(3), 319-336. https://doi.org/10.1016/j.compcom.2005.05.004

Teo, C. L., Tan, S. C., & Chan, C. K. (2021). Pedagogical transformation and teacher learning for knowledge building: Turning COVID-19 challenges into opportunities. *Canadian Journal of Learning and Technology*, *47*(4). https://doi.org/10.21432/cjlt28057

Towndrow, P. A., Nelson, M. E., & Yusuf, W. F. B. M. (2013). Squaring literacy assessment with multimodal design: An analytic case for semiotic awareness. *Journal of Literacy Research*, *45*(4), 327-355. https://doi.org/10.1177/1086296X13504155

Valeiras-Jurado, J., Ruiz-Madrid, M. N., & Jacobs, G. (2018). Revisiting persuasion in oral academic and professional genres: Towards a methodological framework for multimodal discourse analysis of research dissemination talks. *Ibérica: Revista de la Asociación Europea de Lenguas para Fines Específicos (AELFE)*, *35*, 93-118.

Wingrove, P. (2017). How suitable are TED Talks for academic listening? *Journal of English for Academic Purposes*, *30*, 79-95. https://doi.org/10.1016/j.jeap.2017.10.010

Zhang, Y., Machin, D., & Song, T. (2015). Visual forms of address in social media discourse: The case of a science communication website. *Journal of Multicultural Discourses*, *10*(2), 236-252. http://dx.doi.org/10.1080/17447143.2015.1042384

Authors

Jingxin Jiang is an Associate Professor at Chongqing Open University, China, and Ph.D. candidate at the National Institute of Education, Nanyang Technological University, Singapore. Her research interest is multimodal discourse analysis, multiliteracy, and online learning. *Email*: jingxinjiang@hotmail.com

Fei Victor Lim is an Assistant Professor at the National Institute of Education, Nanyang Technological University, Singapore. He researches and teaches on multiliteracies, multimodal discourse analyses, and digital learning. *Email*: victor.lim@nie.edu.sg

CJLT RCAT
Canadian Journal of Learning and Technology
La Revue canadienne de l'apprentissage et de la technologie

Volume 48 (4) Special Issue 2022

Defining and Exploring Broadband Connections and Education Solutions in Canada's North

Définir et explorer les connexions haut débit et les solutions éducatives dans le nord du Canada

***Tammy Soanes-White**, Athabasca University and Aurora College, Canada*

Abstract

The use of technology and need for connection across distance permeates all education environments; nowhere is this more important than in Canada's Northwest Territories. Broadband and telecommunications issues within the Northwest Territories are complex due to its vast geographical area and community dispersion, making connectivity and accessibility inconsistent. Due to these conditions, the North relies on a variety of broadband solutions to improve Internet speeds and access to education at a distance. This paper analyzes the impacts that broadband capacity and Internet access have on remote education by examining geographic information system data, which offers a framework that connects spatial and temporal data to analyse accessibility of remote education. Characteristics such as spatial location of communities, infrastructure (road systems), and the overlay of various broadband options will illustrate constraints and (dis)connectivity in various regions and inform readers about the complexity of remote connections. Analysis of current upload and download speeds from various regions and their impact on access to education supports geospatial data and analysis that the digital divide in remote regions of Canada has increased and is widening. Improving equitable access to postsecondary education will require a greater reliance on technology-enabled practices to improve learning opportunities.

*Keywords***:** Accessibility; Broadband; Connectivity; Critical digital pedagogy; Geographical information systems; Remote learning

Résumé

L'utilisation de la technologie et le besoin de connexion à distance sont présents dans tous les milieux de l'éducation, et nulle part ailleurs cela n'est plus important que dans les Territoires du Nord-Ouest du Canada. Les problèmes liés à la connexion haut débit et aux télécommunications dans les

Territoires du Nord-Ouest sont complexes en raison de la vaste étendue géographique et de la dispersion des communautés, ce qui rend la connectivité et l'accessibilité inconsistantes. En raison de ces conditions, le Nord s'appuie sur une variété de solutions haut débit pour améliorer les vitesses d'Internet et l'accès à l'éducation à distance. Le présent document analyse les répercussions de la capacité haut débit et de l'accès à Internet sur l'éducation à distance en examinant les données du système d'information géographique, qui offre un cadre reliant les données spatiales et temporelles pour analyser l'accessibilité de l'éducation à distance. Des caractéristiques telles que la localisation spatiale des communautés, les infrastructures (réseaux routiers) et la superposition de diverses options de haut débit illustreront les contraintes et la (manque de) connectivité dans diverses régions et informeront les lecteurs sur la complexité des connexions à distance. L'analyse des vitesses actuelles de mise en ligne et de téléchargement de diverses régions et de leur incidence sur l'accès à l'éducation appuie les données et l'analyse géospatiales selon laquelle la fracture numérique dans les régions éloignées du Canada a augmenté et continue de s'élargir. L'amélioration de l'accès équitable à l'éducation postsecondaire nécessitera un recours accru aux pratiques axées sur la technologie pour améliorer les possibilités d'apprentissage.

Mots clés : accessibilité ; haut débit ; connectivité ; systèmes d'information géographique ; pédagogie numérique critique ; apprentissage à distance

Introduction

The Northwest Territories (NWT), Canada's west central territory that encompasses both arctic and sub-arctic regions and is home to 41,000 of Canada's most remote inhabitants and is the focus of this paper. Residents of the NWT live in 33 communities and on one reservation, dispersed throughout this vast 1.14 million square kilometer region (Statistics Canada, 2016). This region is the traditional lands of the Dene, Inuit, and Metis people, who comprise approximately 50% of the total population (Government of the Northwest Territories, 2021). Life and living in this region require individuals to be fiercely independent, yet adaptable and supportive of the interdependent needs of various cultures, communities, and community members, specifically in education. Given this environment, many of the NWT broadband and telecommunications issues exist because of the vast geographical territory and dispersion of people, resulting in a heavy reliance on a multitude of broadband solutions depending on the location and connection types available. The intention of this paper is to define and describe the broadband and telecommunications options available in the NWT using a geospatial framework and to discuss current data speeds based on the connectivity options available in the various regions. Understanding diverse capacities based on geospatial characteristics is central to understanding the difficulty in ensuring equitable access to postsecondary and higher education and the necessity in developing innovative solutions to reaching students across the NWT. The article concludes with thoughts on two predominant challenges of transmission and application, and consideration of innovations to improve equitable access to remote postsecondary and higher education.

Background

Many issues exist regarding equitable access to postsecondary and higher education in the NWT. Broadband and Internet connectivity are perennial problems that restrict reaching students at a distance. This is primarily due to the location of remote communities and the inability to get stable, affordable, and standardized broadband capacity into these locations. Infrastructure development is another issue that restricts the further development of wired connections into communities. Without road systems, developing high speed fibre-optic infrastructure and connections is not possible. Geographical dispersion of remote populations across a vast territory, coupled with inaccessible and unstable broadband capacity contextualize the difficulties in extending distance education to remote communities. Due to these characteristics, a variety of innovative solutions have been used to mitigate inequitable access to education using various broadband types depending on the location and access to each community.

Using Geographical Information System Data

Geographic information systems (GIS) offers a framework to connect spatial and temporal characteristics allowing for "the integration of a spatial component into a larger framework" (Marti-Henneberg, 2011, p. 1) and permits the integration of "geographical features with tabular data in order to map, analyze, and assess real-world problems" (Dempsey, 2021). The significance of GIS is that it allows for an overlay of spatial and temporal dimensions so that readers can better understand a social or political phenomenon. By providing context, GIS illustrates complexity of relationships, promotes advocacy, and elicits social awareness (McMahon et al., 2017). Within the scope of this paper, GIS offers a means to connect spatial characteristics such as infrastructure development (road access or lack thereof), spatial location (geographical location), broadband connection type (satellite, digital subscriber lines, fibre-optic/coaxial), and data speeds to understand the relationship of broadband capacity to equitable access in remote education at a distance.

How Broadband Travels in the Northwest Territories

Four types of broadband connection exist across the NWT including satellite, digital subscriber lines (DSL), coaxial/fibre-optic, and mobile connections. Figure 1 illustrates the current connection types by community. The predominant broadband connections currently used include satellite or DSL as illustrated in Table 1. Nine communities in the high arctic rely on high orbiting satellites, 20 communities rely on DSL, and five communities have access to coaxial and/or fibre-optic cable, or a combination of fibre-optic and DSL connections (Northwestel Inc, 2021).

Figure 1

NorthwesTel Inc.[1] Internet Type by Community in 2022

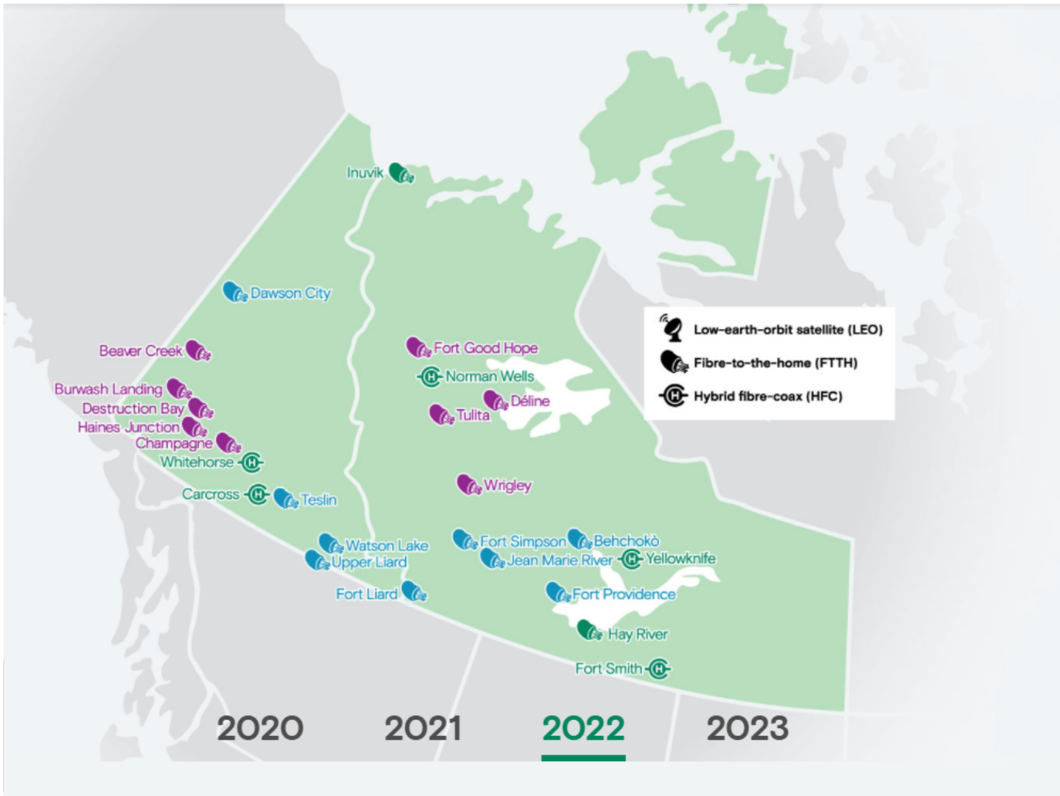


Table 1

Broadband Connection Type by Community

Community	Satellite connected	DSL connected	Coaxial/fibre-optic connected
Aklavik		*DSL*	
Behchoko		*DSL*	
Coville Lake	*Satellite*		
Deline		*DSL*	
Fort Good Hope		*DSL*	
Fort Liard		*DSL*	
Fort McPherson		*DSL*	
Fort Providence		*DSL*	

[1] https://everycommunity.nwtel.ca/

Community	Satellite connected	DSL connected	Coaxial/fibre-optic connected
Fort Resolution		*DSL*	
Fort Simpson		*DSL*	
Fort Smith			*Coaxial/fibre-optic*
Gameti	*Satellite*		
Hay River			*Coaxial/fibre-optic*
Inuvik		*DSL*	*Coaxial/fibre-optic*
Lutsel K'e	*Satellite*		
Norman Wells			*Coaxial/fibre-optic*
Paulatuk	*Satellite*		
Sachs Harbour	*Satellite*		
Tsiigehtchic		*DSL*	
Tuktoyaktuk		*DSL*	
Tulita		*DSL*	
Ulukhaktok	*Satellite*		
Wha Ti		*DSL*	
Yellowknife			*Coaxial/fibre-optic*

Source: Government of the Northwest Territories, Department of Infrastructure. NT.

Defining Connection Types

Each form of broadband connection has its strengths and its challenges. Connection types depend on community access and availability of infrastructure. Communities with road access can connect to fibre-optic and coaxial services. Communities with limited or seasonal winter road access must rely on existing wired options including DSL. Remote fly-in communities rely predominantly on satellite connections. The following section describes each of the options currently used in the NWT.

Satellite Connections

Geostationary Satellites

Geostationary satellites are high-orbiting satellites stationed at the equator approximately 35,000 kilometres above the earth's surface. Each satellite revolves with the earth, rotating at the same speed as the earth's orbital spin, so the satellite moves at the same rate and speed as the earth's axis. These satellites have a line of sight with 40% of the earth's surface except for small spherical areas at the north and south poles; each separated by 120 degrees of latitude, requiring only three satellites to cover the entire planet. These satellites use an earth-bound directional antenna, accessible by small dishes on the earth's surface and left in one position once established. Highly directional antennas reduce interference from other surface-based connectivity. The major drawback of this type of broadband connection is the narrow orbital zone around the equator limiting the number of potential satellites that can be used without risk of collision. Other limitations include the latency time required for signals to travel up to the satellite and return to earth; the gravitational interaction that disrupts the speed consistency of connections; and solar fades from electro-magnet interference from the sun, which creates noise with the receiving station on earth (TechTarget Contributor, 2021).

Personal computers access satellite connections through modems to household satellite dishes. This dish sends and receives signals from orbiting satellites, allowing broadband access. There are varying levels of connectivity for the end user depending on the type of satellite, the position of the end user, and the satellite and potential disruptions. Table 2 identifies remote NWT communities that currently rely on satellite for broadband connections (Varga, 2021). All these communities are predominantly fly-in communities and accessed by airplane.

Table 2

Broadband Satellite Communities

Community	Satellite or Terrestrial	DCN2011 Bandwidth Up/Down (Mbps)	Offload Bandwidth Up/Down (Mbps)	Offload Monthly Cap (GB)
Colville Lake	Satellite	2/3	768Kbps/5	200
Gameti	Satellite	2/4	768Kbps/5	200
Lutsel K'e	Satellite	2/4	768Kbps/5	200
Paulatuk	Satellite	2/5	768Kbps/5	200
Sachs Harbour	Satellite	2/5	768Kbps/5	200
Trout Lake	Satellite	2/3	768Kbps/5	200
Ulukhaktok	Satellite	2/5	768Kbps/5	200
Wekweti	Satellite	2/4	768Kbps/5	200

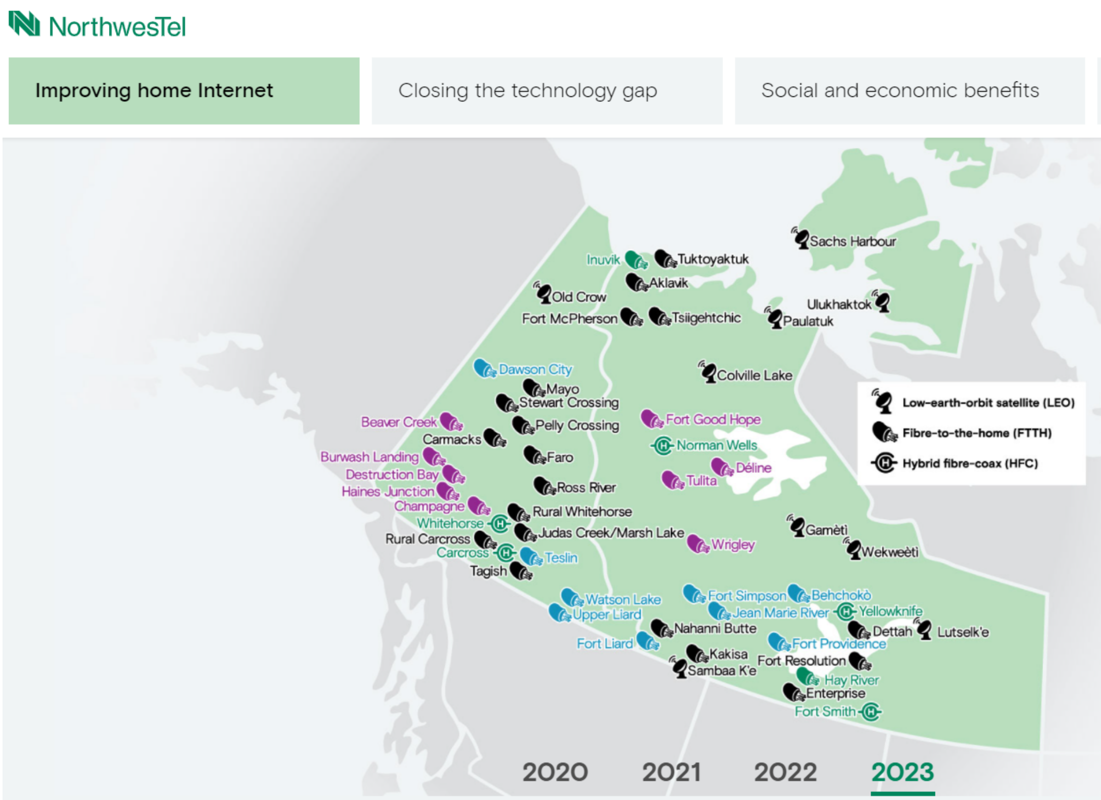
Source: Varga, 2021.

Low Earth Orbital Satellites

Low earth orbital (LEO) systems are a collection of satellites, called swarms, orbiting a few hundred kilometers above the earth's surface. These satellites rotate around the earth's surface and take between 90 minutes and a few hours to complete a full rotation around the earth, connecting with various points on the planet. These swarms of satellites are strategically placed so there is always one satellite in line of sight for connectivity. These LEOs act as repeaters in a global network, carrying signals in a continuous connection across the network. "A LEO satellite system allows the use of simple, non-directional antennas, offers reduced latency, and does not suffer from solar fade." (TechTarget Contributor, 2021). Figure 2 illustrates that by 2023, the planned broadband connection to most remote satellite-connected communities in the NWT will rely on LEO, not geostationary satellites (Northwestel Inc, 2021). LEOs are generally used in industry such as at remote mine sites.

Figure 2

Map of Proposed LEO Satellite Communities for 2023



Source: Northwestel | Every Community Project (nwtel.ca).

Digital Subscriber Lines

Digital subscriber lines use analog, low pass filters that refine connection quality through existing phone cable lines. Many of the remote communities with road access (all year or winter road) run on DSL connections which are considered low bandwidth connections and run through established copper telephone lines into communities. These copper lines can accommodate multiple forms of data; however, because they were initially constructed to distribute voice data, transferring other forms of data is slower.

Services within the NWT, and specifically in communities outside of Yellowknife, are off loaded to DSL services and shared between government offices and education (K-12 schools and community learning centre) sites in the community. Currently education Internet traffic in communities outside of Yellowknife is offloaded through an NWTel DSL service. The offload bandwidth column in Table 3 below confirms the NWTel DSL service speeds (Varga, 2021). These data illustrate the reduced service capacity when high speed connections transfer to slower, more inferior, DSL connections.

Table 3

Community Bandwidth Speeds and Caps

Community	Satellite or Terrestrial	DCN2011 Bandwidth Up/Down (Mbps)	Offload Bandwidth Up/Down (Mbps)	Offload Monthly Cap (GB)
Coville Lake	Satellite	2/3	768Kbps/5	200
Gameti	Satellite	2/4	768Kbps/5	200
Lutsel K'e	Satellite	2/4	768Kbps/5	200
Paulatuk	Satellite	2/5	768Kbps/5	200
Sachs Harbour	Satellite	2/5	768Kbps/5	200
Trout Lake	Satellite	2/3	768Kbps/5	200
Ulukhaktuk	Satellite	2/5	768Kbps/5	200
Wekweti	Satellite	2/4	768Kbps/5	200
Additional 4 Mbps of Satellite B/W				
Aklavik	Terrestrial	6/6	1/15	250
Behchoko (Edzo)	Terrestrial	2/2	1/15	400
Behchoko (Rae)	Terrestrial	10/10	1/15	400
Deline	Terrestrial	6/6	1/15	250
Dettah	Terrestrial	2/2	1/15	250
Enterprise	Terrestrial	2/2		
Fort Good Hope	Terrestrial	4/4	1/15	250
Fort Liard	Terrestrial	4/4	1/15	400
Fort McPherson	Terrestrial	6/6	1/15	400
Fort Providence	Terrestrial	5/5	1/15	400
Fort Resolution	Terrestrial	4/4	1/15	400
Fort Simpson	Terrestrial	20/20	1/15	400
Fort Smith	Terrestrial	30/30	100/100	Unlimited
Hay River	Terrestrial	40/40	30/120	Unlimited
Inuvik	Terrestrial	50/50	100/100	Unlimited
Jean Marie	Terrestrial	2/2	1/15	250
Kakisa	Terrestrial	2/2		
Nahanni Butte	Terrestrial	2/2	1/15	250
Norman Wells	Terrestrial	15/15	6/80	1100

Community	Satellite or Terrestrial	DCN2011 Bandwidth Up/Down (Mbps)	Offload Bandwidth Up/Down (Mbps)	Offload Monthly Cap (GB)
Tsiigehtchic	Terrestrial	4/4	1/15	250
Tuktoyaktuk	Terrestrial	6/6	1/15	400
Tulita	Terrestrial	5/5	1/15	400
Wha Ti	Terrestrial	3/3	1/15	250
Wrigley	Terrestrial	4/4	1/15	250
Yellowknife	Terrestrial	300/300		

Source: Government of Northwest Territories, Department of Infrastructure, Yellowknife, Canada.

Digital subscriber lines are a stable broadband option; however, lower rates of data transfer negatively affect connection limits, data capacity, widespread access, consistent use, and reliable availability. The exponential growth of data sets and sources has reduced the usefulness of DSL connections.

Cable or Coaxial Connections

Coaxial cable is comprised of two layers of copper used to connect satellite antennae to home devices such as televisions and computers. The central layer is a conducting wire, wrapped in an electric insulator, used to protect and stabilize the electrical current of the coaxial core. Braided copper mesh covers the electrical insulator, allowing both copper lines to run parallel to one another. The outer insulating layer stabilizes and protects the transmission of both copper lines inside the housing. The cable is typically grounded at both ends to dissipate any interference that may occur (McCarthy Earls, 2021). Coaxial cable can increase download speeds and carry larger volumes of data. Bandwidth is generally shared amongst users so when high demand for Internet occurs, speed is generally reduced. Coaxial cable is also used as an Ethernet to connect devices within an organization or home. Ethernet employs a twisted paired cabling system to reduce distortions and increase speed and data size; it is a reliable, traditional, networked method used in schools and organizations, connecting computers using a physical cord. Although Ethernet is popular because it is inexpensive, reliable, and compatible across devices and is still widely used because of speed, security, and reliability, it is more complex than Wi-Fi due to the need for physical connection (Chai et al., 2021; McCarthy Earls, 2021). Internet through coaxial cables have download speeds comparable to fibre-optic speeds; however, comparable upload speeds are not attainable.

Fibre-Optic Cable

Fibre-optic cable carries and transfers data at the speed of light, using glass or plastic fibres. Data can be carried over higher bandwidth and greater distance than DSL or coaxial cables. Fibre-optic cable is considered a medium and a technology containing strands of glass or plastic, as thin as a strand of hair. These strands of glass or plastic are arranged in bundles and used to generate light signals that carry information using light-based technology, pulsing through cables by bending incoming light. A smaller opening in the cable isolates light and provides better connections and transmission of information as light pulses along glass or plastic fibre. The smaller the fibre-optic cable, the greater the distance the information can travel. Single mode cable is used for longer distances because of their limited core size and higher bandwidth capacity by focusing a glass laser light beam. Multimode cable is used for shorter distances as the larger diameter of the cable allows for multi data transfer, happening simultaneously. This is possible because there are larger multiple light pulses, allowing more data transmission and providing higher bandwidth and better connections. Fibre-optic cable can reach transfer speeds greater than 1,000 Mbps. Currently only five communities in the NWT have access to fibre-optic connections including Hay River, Inuvik, Fort Smith, Norman Wells, and Yellowknife. Northwestel developed fibre-optic connections in 2021 to extend fibre-optic cable to the communities of Fort Providence, Fort Simpson, Fort Liard, Behchoko, and Dettah (Northwestel Inc, 2021).

Theoretical Position

Creating more equitable access to stable and consistent Internet is necessary to ensure that NWT residents have consistent access to postsecondary and higher education. This theoretical position is grounded in critical digital pedagogy (CDP), a non-neutral approach to teaching and learning that challenges the status quo in education, supporting social change and raising consciousness while shaping society through liberatory praxis. Critical digital pedagogy fosters agency and empowers learners through “reflective dialogue within web-based tools” (Stommel, 2014). Critical digital pedagogy deconstructs power structures and social impediments to learning within digital spaces and is a deeply personal, political, and subjective endeavor. CDP invites the whole person in an ongoing and recursive process of discovery (Hall, 2016). Critical digital pedagogy is defined here as a strategy and practice of teaching that deconstructs and dismantles institutional and societal impediments to learning by liberating social, technical, and political structures.

Digital refers to more than educational technology. It is about using right technology to improve learning conditions and create equitable access for all in learning spaces. Our use of digital pedagogy needs to consider the relational needs, accessibility of tools, and openness to learning resources. Digital use also needs to positively direct improvements to institutional supports and opportunities for students’ engagement between students. Stommel et al. (2020) states the importance of human connections in the use and development of digital learning. “Digital pedagogy is about human relationships, the complexity of humans working together with other humans – the challenges of finding ways to teach through a screen, not to a screen” (Stommel et al., 2020, p. 7).

Critical digital pedagogy, arisen from work around the globe, embraces a social justice lens. Many advocates, researchers, and pedagogues have enlisted social action to dismantle power structures and embrace a more equitable and fair education system that embraces diversity and invites non-traditional and unrepresented voices in education. This has been accomplished through various means, including the politicizing of CDP through liberation and care and pedagogies of kindness (Denial, 2020; Stommel, 2014) and through innovative practices such as dismantling classroom power structures, inviting students' voices, and deconstructing traditional curricula through new instructional design strategies (Bali, 2014; Friend, 2020). Critical digital pedagogy also invites pedagogical alterity through praxis specifically through elevating conversations and voices involving people with disabilities, minority groups, immigrant populations, Indigenous nations, and underrepresented populations such as prisoners (Godden & Womack, 2020; Stommel, 2014; Stommel et al., 2020). Finally, CDP elevates pedagogy through its practical applications to the scholarship of teaching and learning through conversations around design, trust, and discovery (Morris & Eyler, 2020). Critical digital pedagogy is a platform that invites exploration of paradigm-altering ways of improving and expanding engagement and discovery through non-traditional approach to both teaching and learning. It is through this CDP lens that efforts to improve fair and consistent access to postsecondary education for all NWT residents is explored.

Discussion

To understand the challenge of improving access we need to first understand the problems of transmission and application. Much work is being done to understand the current environment and this discussion focuses on the work of DigitalNWT and their research conducted to improve digital literacy at the community level, to influence digital impacts on courses and programs, and to improve affordable digital access through reliable connections and affordable Internet options (McMahon et al., 2021). Their research results summarized below provide evidence of the broadband and telecommunications challenges that exist in the NWT.

Upload and Download Analysis of Communities

The following data was collected by DigitalNWT using Canadian Internet Registration Authority Internet performance test results from 2019–2021 (DigitalNWT, 2021).[2] This report analyzed data regarding the type, speed, variability, and broadband connection across the NWT. This organization compared broadband data in literature to infer how NWT's broadband services compared to standard upload and download ranges. Table 4 summarizes the range of normal speeds experienced using various broadband connection types. Based on existing literature, the average speeds observed are at the low end in each connection type. There is concern that those with the least amount of access and slowest speeds are the ones with band usage caps and extra service charges for the services

[2] During this time 1,438 speed tests were conducted throughout 24 NWT communities. These tests summarized the community observed, the download and upload speeds the number of test counts, and connection types. This research was conducted to "strengthen digital literacy", to "inform course development and delivery" to conduct "research activities regarding internet access, affordability and reliability" (DigitalNWT, 2021). The findings are summarized in the Telecom notice of consultation CRTC 2020-367, *"Call for comments – review of the Commission's regulatory framework for Northwestel Inc. and the state of telecommunications services in Canada's North."* and on the DigitalNWT website.

provided. Below is a summary and analysis of each broadband type based on community location and data speeds.

Table 4

DSL vs. Cable vs. Fibre-optic Speeds

Technology Type	Download Speed Range	Upload Speed range
DSL	5-35 Mbps	1-10 Mbps
Cable	10-500 Mbps	5-50 Mbps
Fibre-optic	250-1000 Mbps	250-1000 Mbps

Source: Cooper, 2021.

Analysis of Satellite Community Data

Satellite-connected communities are primarily located in the high arctic with limited road access and are typically reached through air access. Download speeds for these communities have a high positive skewness due to digital research data from the community of Lutsel K'e located in the sub-arctic region (DigitalNWT, 2021). Upload speeds are more modestly skewed across the communities, demonstrating more consistency in upload speeds. Unfortunately, satellite data speeds are not available in the literature, so no comparisons can be made for NWT download and upload speeds.

Analysis of DSL Community Data

Communities connected through DSL may or may not have road access, are located across both arctic and sub-arctic regions, are smaller more remote communities, and have existing phone lines. If road access exists, the access may be seasonal. When NWT communities using DSL connections are compared to national averages of communities across Canada that rely on these connection types, the NWT communities are on the low end of documented ranges in the literature. Typical download speeds range from 5–35 Mbps and upload speeds range from 1–10 Mbps, as illustrated in Table 4. Considerably lower than average download and upload speeds for DSL, NWT communities were observed from the data collected (DigitalNWT, 2021). Some communities have access to both DSL and coaxial connections. In some of these communities, identified with DSL usage, moderate positive skewness resulted. An example of this is the community of Inuvik that uses coaxial connections for health care and education but DSL connections for residential use, potentially distorting DSL results. As expected, when Inuvik data is removed the deviation of the data is reduced and more truly reflects predictable DSL data results. Documented speeds fall below the ranges identified in literature of 5–35 Mbps and 1–10 Mbps, respectively.

Analysis of Fibre-optic/Coaxial Community Data

All fibre-optic connected communities have road access and access to developed fibre-optic cable infrastructure. Fibre-optic average speeds for fibre/coaxial NWT communities are on the low range compared to the documented range of download speeds ranging from 10-500 Mbps for cable and 250-1,000 Mbps for fibre-optic speeds. Upload speeds for fibre-optic/coaxial communities are also consistently low, compared to 5-50 Mbps for cable and 250-1,000 Mbps for fibre-optic connection speeds recorded in literature. Heavy reliance on cable connections at the user end of the connection distorts the upstream speeds of the fibre-optic connections. Territorial decision makers and providers of broadband service providers must also consider where and when cable connects to the data stream. Because of the placement of the connections to Yellowknife, the fibre-optic download data speeds are skewed compared to communities of Fort Smith, Hay River, and Norman Wells. Upload speeds are consistent across the four communities, resulting in a normal distribution for the four communities (DigitalNWT, 2021).

Meaning of Data for NWT Communities and Residents

What this data means for the community members of the NWT is that students are not able to access postsecondary or higher education from most communities. In fact, students are required to move to three of the larger centres of Inuvik, Fort Smith, and Yellowknife to attend classes on campus. As identified above, Internet speeds, data usage fees, and upload and download speeds make online learning in remote communities almost impossible. Current efforts, such as the DNWT Nimble project, are exploring the possibility of developing locally managed mesh wireless intranet systems as one solution to reducing the digital divide. Another initiative includes discussions with remote mining companies to explore cloud-based solutions to address these access divides.

Considerations for Future Development

Spatial analysis combined with broadband usage allows us to explain and understand how and why there is inequitable access to remote education. The differences that exist between communities are related to infrastructure development (road systems), the location of each community, and the telecommunication options available. The geographical dispersion of remote populations negatively influences business decisions and restrict further development of equitable access to education at a distance for communities and students. Analysis of upload and download speeds further validates and confirms these conclusions. Further development of remote GIS data is necessary to promote a deeper understanding of the challenges and potential solutions of NWT remote education at a distance. Systemic quantitative analysis can be used to validate the current reality and advocate for further development of remote populations.

This discussion of future developments has prompted several questions related to remote education. Do broadband types influence the development (or lack thereof) of educational opportunities available in remote communities? How responsive are institutions at improving equitable access to remote education options? Are national standards in broadband capacity actually universal? To what extent is the reduced responsiveness to educational requests due to smaller community populations? Is capital development restricted because low populations in remote communities do not result in profitability and return on investment for corporate service providers? Is this fair; is this equitable? If there are no business models to support broadband development, what alternative political and social justification is necessary to extend national broadband standards to remote regions? Who should pay for these developments? Finally, would the availability of stable broadband and access to the Internet encourage distance learning in remote communities as opposed to an outward migration of young community members to larger urban centres? Would this benefit communities and improve or detract from the quality of remote living?

Conclusion

Although the variability of broadband connectivity is an everyday reality in the Northwest Territories, in Canada, the type of access deeply influences the speed and reliability of community connections. Much of what is done in education now relies on technological use, limiting accessibility to the most remote students in the NWT. The remotest communities are the most disadvantaged, due in part to infrastructure development, low population density, broadband options, and a lack of profitability in further telecommunications development. An examination of broadband data speeds further validates the claims that inequitable access to broadband exists between communities (DigitalNWT, 2021). Download and upload speeds make heavy data files impossible to access at the community level. Inequities are further complicated due to caps placed on data use and time at the community levels. Finally, as networked learning relies heavily on video files, many students are not able to even retrieve videos or data dense files for learning. The five largest communities within the North have access to exponentially larger download and upload speeds in comparison to DSL, or satellite connected communities, creating larger inequities for smaller, more remote communities.

Plans and development of fibre-optic cable connections continue to expand faster connections; however, this does not resolve the short-term issues of the most remote communities or for students studying at a distance. Infrastructure development costs per location are approximately $250,000 that may or may not reduce the current operational costs of enhanced services. Although the impact of broadband enhancements would create a paradigm shift for remote learners and education at a distance, many communities do not have the time, skills, or money for further development at this time. More work is necessary to support and develop community initiatives and improve infrastructure. In actuality, the ongoing evolution of broadband connectivity and Internet access is becoming even more stratified, as larger road-access communities receive exponentially faster speeds than remote satellite-based communities that continue to rely on high-orbiting satellites at slower speeds. Plans for NorthwesTel telecommunications development by 2023 will not bring fairness to the most remote communities in the NWT (see Figure 2). Eight communities will still require satellite feeds to ensure broadband access for those community members. Communities relying on satellite connections still receive exponentially slower connections, monthly usage caps, and unacceptable usage fees. As a result, they are hit with low broadband access and imposed restrictions on upload and download costs, thereby disadvantaging these communities from an ever-increasing need for telecommunications standards, necessary in today's world.

Variability of broadband connectivity continues to challenge educators in remote communities, making fair and equitable access a constant challenge in postsecondary education. Networked learning relies heavily on data-dense files that are downloaded quickly, reliably, and are easily accessible for learning which is impossible to access at remote sites using slow Internet infrastructure. These are the reasons innovative solutions are beginning to emerge.

Two main constraints of transmission and application will continue to challenge educators for the foreseeable future. Some viable solutions that are currently being pursued include the use of LEOs, mesh networks, and cloud-based solutions. Other options under consideration include the development of a northern-shared data centre, the development and creation of load servers, and the use of innovative data security solutions. The DNWT Nimble project (e.g., locally managed, mesh wireless intranet systems) is another example of an innovative solution to close the broadband access divide (DigitalNWT, 2021).

These challenges, however, have not eliminated educational opportunities. Not surprisingly, all levels of education have been confronted with these limitations and have risen above these challenges to find creative solutions to develop, enhance, and extend learning. Examples of current solutions include shared instructors across remote communities, the use of data sticks, loanable computers, and the use of low bandwidth applications. These global issues have found resolutions in remote spaces around the world and remote educators are leading the way in augmenting and advancing education within these constraints. It is through this continued work that real time solutions are found and connections continue to be made.

Acknowledgement

Initially presented at the virtual symposium: Rethinking Online Education in the Knowledge Society with Emerging Technology jointly hosted by the Chongqing Open University, China, Athabasca University, Canada, and Beijing Normal University, China.

References

Bali, M. (2014). Critical pedagogies: Intentions and realities. In J. Stommel, C. Friend, & S. Morris (Eds.), *Critical digital pedagogy: A collection* (pp. 67-74). Hybrid Pedagogy.

Chai, W., Irei, A., & Burke, J. (2021). *Ethernet*. Tech Target. https://searchnetworking.techtarget.com/definition/Ethernet

Cooper, T. (2021). *DSL vs Cable vs Fiber: Comparing Internet Options*. Broadband Now. https://broadbandnow.com/guides/dsl-vs-cable-vs-fiber

Dempsey, C. (2021, March 16). *What is GIS?* GIS Lounge. https://www.gislounge.com/author/caitlin

Denial, C. (2020). A pedagogy of kindness. In J. Stommel, C. Friend, & S. Morris (Eds.), *Citical digital pedagogy: A collection* (pp. 212-218). Hybrid Pedagogy.

DigitalNWT. (2021). *Stay Up to Date on the Digital NWT Project*. DigitalNWT. https://www.digitalnwt.ca/news

Friend, C. (2020). Finding my voice as a minority teacher. In J. Stommel, C. Friend, & S. M. Morris (Eds.), *Critical digital pedagogy: A collection* (pp. 180-186). Hybrid Pedagogy.

Godden, R. H., & Womack, A.-M. (2020). Making disability part of the conversation: Combatting inaccessible spaces and logics. In J. Stommel, C. Friend, & S. M. Morris (Eds.), *Critical digital pedagogy: A collection* (pp. 169-173). Hybrid Pedagogy.

Government of the Northwest Territories. (2021, January 12). *Population estimates by community*. NWT Bureau of Statistics. https://www.statsnwt.ca/population/population-estimates/bycommunity.php

Hall, L. (2016). *Critical Digital Pedagogy* [video]. YouTube. https://www.youtube.com/watch?v=5wzbAcoljzE

Marti-Henneberg, J. (2011). Geographical information systems and the study of history. *Journal of Interdisciplinary History, 42*(1), 1-13. https://doi.org/10.1162/JINH_a_00202

McCarthy Earls, E. (2021). *Coaxial Cable*. Tech Target. https://searchnetworking.techtarget.com/definition/coaxial-cable-illustrated

McMahon, R., Akcayir, M., McNally, M. B., & Okheena, S. (2021). Making Sense of Digital Inequalities in Remote Contexts: Conceptions of and responses to connectivity challenges in the Northwest Territories, Canada. *International Journal of Communication*, 5229-5251. https://ijoc.org/index.php/ijoc/article/view/18213

McMahon, R., Smith, T. J., & Whiteduck, T. (2017). Reclaiming geospatial data and GIS design for Indigenous-led telecommunications policy advocacy: A process discussion of mapping broadband availability in remote northern regions of Canada. *Journal of Information Policy, 7*, 423-449. https://doi.org/10.5325/jinfopoli.7.2017.0423

Morris , S. M., & Eyler, J. (2020). Conversations: Instructional design, trust and discovery. In J. Stommel, C. Friend, & S. M. Morris (Eds.), *Critical digital pedagogy: A collection* (pp. 227-235). Hybrid Pedagogy.

Northwestel Inc. (2021). *Improving Home Internet*. NorthwesTel. https://everycommunity.nwtel.ca/

Statistics Canada. (2016). *Census profile, 2016 census*. Statistics Canada. https://www12.statcan.gc.ca/census-recensement/2016

Stommel, J. (2014). *Citical Digital Pedagogy: Adefinition*. Hybrid Pedagogy. https://hybridpedagogy.org/critical-digital-pedagogy-definition/

Stommel, J. (2020). Forward. In J. Stommel, C. Friend, & S. M. Morris (Eds.), *Critical digital pedagogy: A collection* (p. 7). Hybrid Pedagogy.

Stommel, J., Friend, C., & Morris, S. (2020). *Critical digital pedagogy: A collection.* Hybrid Pedagogy.

Stommel, J., & Morris, S. (2018). *An urgency of teachers: The work of critical digital pedagogy.* Press Books.

TechTarget Contributor. (2021). *Geostationary satellite*. Tech Target. https://www.techtarget.com/searchmobilecomputing/definition/geostationary-satellite

Varga, E. (2021). Department of Infrastructure - GNWT. (T. Soanes-White, Interviewer) Yellowknife, NT, Canada.

Author

Tammy Soanes-White is a doctoral student in the Athabasca University Distance Education program and a researcher and Adult Learning Specialist in the Centre for Teaching and Learning at Aurora College, NT, Canada. She is a northern researcher and academic who promotes and advocates for technology-enabled solutions to improve remote education in the Northwest Territories. Currently pursuing a Doctorate in Education, specializing in Distance Education, Tammy's research explores remoteness and its effect on higher education access and the importance of connectedness and connectivity within program design and delivery. Tammy has been involved in research and evaluation, examining a variety of solutions to engage and teach learners across the NWT over the past 25 years. During that time, many solutions have relied on a variety of teaching approaches, while considering the contextual relevance and viability of solutions in remote communities. Her interests are in improving students' experiences and success through blended and face-to-face learning. Email: tsoanes-white@auroracollege.nt.ca

CJLT RCAT
Canadian Journal of Learning and Technology
La Revue canadienne de l'apprentissage et de la technologie

Volume 48 (4) Special Issue 2022

Analysis of the Status and Influencing Factors of Online Learning

Analyse de l'état et des facteurs d'influence de l'apprentissage en ligne

***Jiaju He**, Faculty of Education, Beijing Normal University, China*
***Hong Zhao**, Faculty of Education, Beijing Normal University, China*
***Fei Jiang**, Faculty of Education, Beijing Normal University, China*

Abstract

During the COVID-19 prevention and control period, large-scale online education was the largest digital transformation practice in education in human history. This study launched a questionnaire survey on primary and high school students. The survey was conducted from four aspects: demographics, online learning preparation, the online learning situations, and online learning experience. This study thoroughly investigated the status and problems of students' online learning and analysed the characteristics of students' online learning and the differences amongst grades. The study found that students have high adaptability and continuance intention to online learning.

This study found that students also had some learning difficulties in the process of online learning, mainly manifested by lack of interaction, difficulty in concentration, and lack of learning initiative. There were significant differences among different grades. The overall situation of junior high school students' online learning is better than that of primary school students and senior high school students.

Keywords: Primary and high school; Online learning; Suspension of school without suspending learning; Influencing factors

Résumé

Pendant la période de prévention et de contrôle du COVID-19, l'enseignement en ligne à grande échelle a été la plus grande pratique d'informatisation de l'éducation de l'histoire humaine. Cette étude a lancé une enquête par questionnaire sur les élèves du primaire et du secondaire. L'enquête a été menée sous quatre aspects : démographie, préparation à l'apprentissage en ligne, contexte de l'apprentissage en ligne et expérience de l'apprentissage en ligne. Cette étude a examiné de manière approfondie le statut et les problèmes de l'apprentissage en ligne des étudiants et a analysé les caractéristiques de l'apprentissage en ligne des étudiants et les différences entre les classes. L'étude a révélé que les étudiants ont une grande capacité d'adaptation et une intention de poursuivre l'apprentissage en ligne.

Les étudiants ont également quelques difficultés d'apprentissage dans le processus d'apprentissage en ligne, qui se manifestent principalement par un manque d'interaction, des difficultés de concentration et un manque d'initiative en termes d'apprentissage. Il existe des différences significatives entre les différentes classes. La situation générale de l'apprentissage en ligne des élèves du premier cycle du secondaire est meilleure que celle des élèves du primaire et du deuxième cycle du secondaire.

Mots clés : École primaire et secondaire ; apprentissage en ligne ; suspension de l'école sans suspension de l'apprentissage ; facteurs d'influence

Introduction

During the COVID-19 epidemic prevention and control period, online education became the main mode of education in China. Online education is flexible and can cross the constraints of time and space, but it also has the limitation of separating the teaching and learning process. If not appropriately designed, organized, and implemented, it can easily have a negative impact on the effectiveness of students' online learning due to inadequate teacher supervision, insufficient parental supervision, and students' weak self-control. J. X. Wang et al. (2020) conducted a large-scale survey in Xiaogan City in the Hubei Province and found some potential factors affecting the development of online education, including the concept of online education, security and supply, teacher and students' literacy and competence, the quality of ICT in education, and more. D.D. Wang et al. (2020) carried out a nationwide online questionnaire survey inquiring into the attitudes of different subjects towards online education. They found that educational administrators had an encouraging and supportive attitude, school administrators were relatively positive, teachers had a positive attitude but a sense of anxiety, students' attitudes differed significantly between different areas and grades, and parents had high expectations alongside high concerns.

Indeed, in the face of the largest scale of digital transformation practice in education in human history, not only the serviceability of platforms and resources are facing challenges, but teachers' teaching abilities and students' online learning abilities are also facing a big challenge. How to effectively organize online education is a big problem. Therefore, this study investigated K12 students in China to learn about their online learning situations and experience and tried to analyze the characteristics and problems of K-12 students' online learning, in order to reveal the problems in practice and provide some suggestions for the reform of China's education informatization.

Research Methodology

This study adopted the questionnaire survey method. The questionnaire consisted of four main sections: demographic characteristics, online learning preparation, online learning situations, and online learning experience. Online learning preparation mainly refers to the psychological and environmental preparation, including previous experience, motivation, and network conditions. Online learning situations mainly refer to the implementation of courses and the performance of students in and after class, including the situation of the online classes, self-regulated learning, and students' preferences. Online learning experience mainly refers to the feelings and perceptions of students in many aspects of online learning, including students' adaptability, recognition, difficulties, and continuance intention in online learning.

In this study, questionnaires were distributed online, and the survey was conducted from March 19 to April 19, 2020. A total of 60,567 questionnaires were collected of which 56,438 valid questionnaires were finally obtained, with an effective response rate of 93.18%. The Cronbach Alpha was used to test the reliability of the questionnaire. The coefficients of the three dimensions of online learning preparation, online learning situations, and online learning experience and the overall questionnaire were 0.943, 0.911, 0.922, and 0.920, respectively. Meanwhile, KMO and Bartlett's Test were used to test the validity. The KMO value was 0.956, which was above 0.7, and the p-value of the Bartlett test was less than 0.01. As such, this questionnaire has good reliability and validity.

The questionnaire sample covered 34 provinces in China. The proportion of male students was 53.37%, while female students accounted for 46.63%. The number of primary school students was the highest (47.02%), followed by junior high school students (36.83%), and the smallest number were senior high school students (16.15%). The biggest number of students came from urban areas (60.06%), while 13.80% and 15.76% came from counties and townships, and the number of rural students was the least (10.39%).

Results

Online Learning Preparation

Online Learning Previous Experience

Before COVID-19, 41.66% of students overall had online learning experience. The largest group was senior high school students, with a proportion of 45.77%. The second was junior high school students, where the proportion was 42.30%. The last was primary school students, where the proportion was 39.75%. One-to-many online live classes were the main learning type, and school subjects were the main online learning content.

Online Learning Motivation

This study investigated the motivation from two aspects: external motivations (including school requirements and parental demands) and internal motivations (including students' personal interests and needs). This item was multiple choice. From Table 1, students were mainly motivated by their personal needs, followed by requests from parents and school requirements, and finally by their personal interests. The differences between grades were that primary school students were mainly driven by parental requests, while high school students were primarily motivated by personal needs.

Table 1

Online Learning Motivation

Grade	External motivation		Internal motivation	
	School requirement	Parental demand	Personal interest	Personal need
Primary school	33.83%	46.58%	28.87%	43.59%
Junior high school	41.44%	43.16%	26.50%	50.32%
Senior high school	48.99%	27.36%	20.30%	52.01%

Network Condition

The results show that the network environment was generally good. 66.65% of the participants said they had good Internet connections and 33.35% of participants reported network problems, such as network latency and disconnection.

Online Learning Situations of Students

This part surveyed three aspects: live online class performance, self-regulated learning, and online learning preferences.

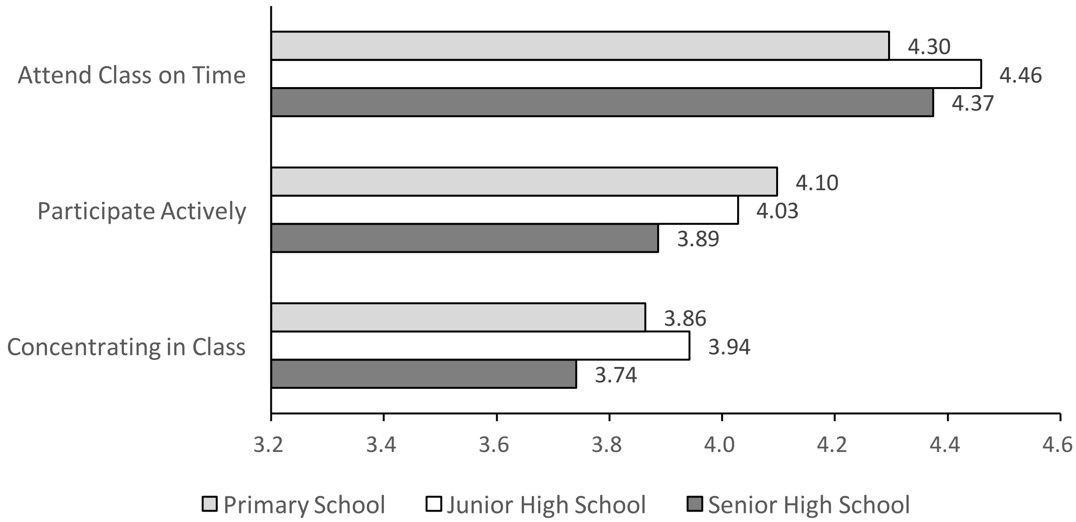
Live Online Class Performance

The average length of online classes for primary and high school students was over 3 hours per day and showed an increasing trend by grade level. This research used a five-point scale for participants to rate themselves on three dimensions: attending the live online class on time, participating actively in class activities, and concentrating in class (Figure 1).

Overall, students' self-perception of their online learning performance was good, with scores close to 4 on all dimensions. Attending class on time scored over 4 points, followed by participating actively in activities. In comparison, students perceived themselves to be weaker in terms of concentrating in class. There were differences in different grades. Junior high school students were generally better at online learning performance than in other grades; primary school students were the most active in class activities; and senior high school students were the worst of the three levels in all dimensions except for attending class on time.

Figure 1

Online Class Situation



Self-regulated Learning

As previous research mentioned, self-regulated learning ability is a key factor to online learning. A five-point scale was conducted in this part from five aspects: learning plan, finishing the homework on time, interaction with the teacher and students, self-management, and self-evaluation (Figure 2). Overall, students scored 3–4 points on each dimension, indicating that their self-regulated learning was at an intermediate level. The highest was the dimension of completing homework on time, with a score of over 4, followed by self-management of learning. While active communication and self-evaluation scored similarly, the score of making a learning plan was the lowest. In terms of different grades, junior high school students' self-regulated learning performance was generally better than other grades. On the contrary, primary school students' performance in all dimensions was the worst, especially in the dimension of self-management, which had a large gap from other grade students.

Learning support is important for students' self-regulated learning. Table 2 shows the main learning supports were from themselves, teachers, and parents. To be specific, primary school students ranked their parents as the most supportive of their learning, followed by teachers, and then themselves, while junior and senior high school students considered themselves first, then their teachers, and finally their parents.

Figure 2

Self-regulated Learning Situation

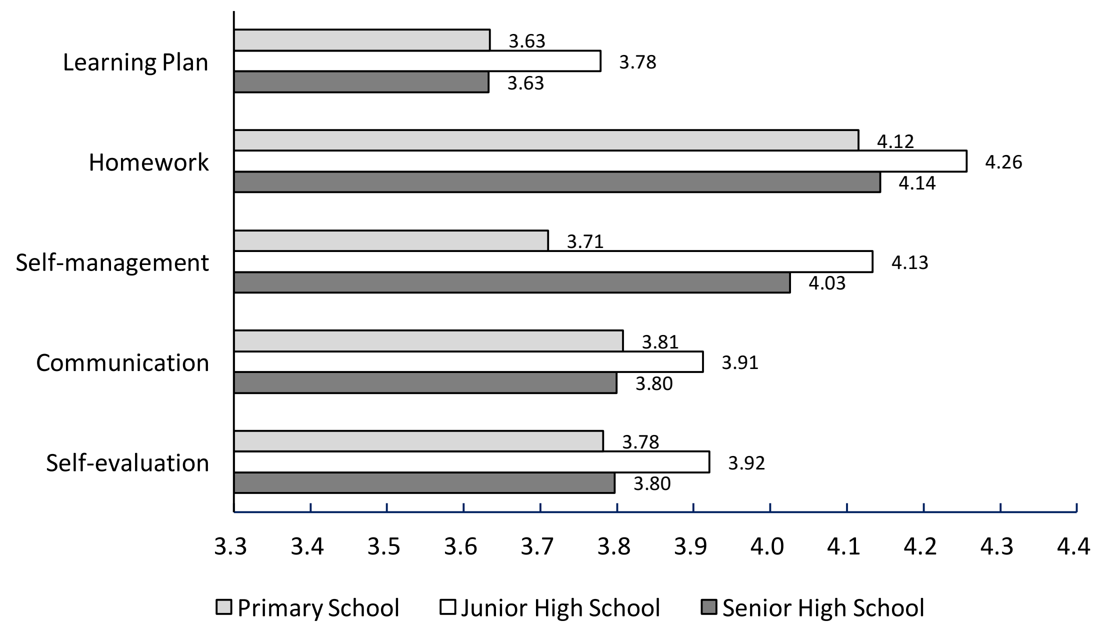


Table 2

Learning Support Situation

Scale	Primary school	Junior high school	Senior high school
Oneself	4.211	4.873	5.358
Teacher	4.737	4.621	4.374
Parent	5.062	3.818	3.064
Fellow student	0.335	1.138	1.436
School	0.527	0.455	0.648
Education administration	0.128	0.096	0.120

Online Learning Preference

This survey investigated primary and high school students' online learning preferences in terms of platforms, resources, course types, and content (Table 3). The result showed that students were most concerned with course content, followed by teachers' guidance, faculty, and learning resources. The last was communication with classmates and platform functions. To clarify the online learning preferences, we asked the participants to rank the options they chose for each dimension (Table 4).

Table 3

Online Learning Concerns

Dimension	Overall	Primary school	Junior high school	Senior high school
Course content	5.53	5.41	5.61	5.68
Teachers' guidance	4.65	4.94	4.56	4.00
Faculty	3.96	3.55	4.01	5.03
Learning resource	3.50	3.16	3.85	3.72
Communication with classmate	2.41	2.13	2.82	2.30
Platform function	2.26	2.09	2.49	2.24

Online Learning Platform Functions. Students mainly focused on the four basic functions of the platforms, including taking notes, assignment submission, in-class communication, and after-class communication. In addition, both primary and junior high school students preferred the function of raising their hands, while senior high school students preferred the function of video playback.

Types of Online Learning Resources. Students' preferences were similar. Textual materials were the favorite resources for all students, followed by course videos, then audio materials, animations, and pictures. The last was educational games.

Online Learning Course Type. All students preferred the three types of one-to-many live classes, online tutoring, and micro-lessons, accounting for 58.32%, 51.94%, and 39.72%, respectively. From the perspective of different grades, primary school students favored online tutoring from teachers, while high school students preferred one-to-many live classes.

Online Learning Course Content. The percentage of students wanting to participate in school subject courses was higher than that of ability training courses. With the rise of grade level, the number of students attending school subject courses increased respectively.

Table 4

Online Learning Preferences

Dimension	Overall	Primary school	Junior high school	Senior high school
Platform function				
Taking note	6.44	5.24	7.59	7.28
Assignment submission	5.96	5.99	6.16	5.39
In-class communication	5.46	5.19	5.79	5.48
After-class communication	4.98	4.90	5.23	4.65
Video playback	4.57	4.21	4.57	5.65
Raise hand (answer question)	3.96	4.19	4.09	3.01
Resource type				
Textual material	4.35	4.04	4.59	4.73
Video	3.86	3.96	3.80	3.75
Audio material	2.99	3.08	2.92	2.89
Animation	2.46	2.62	2.41	2.14
Picture	2.40	2.10	2.57	2.93
Educational game	1.88	2.02	1.90	1.42
Course type				
One-to-more live class	58.32%	51.32%	66.49%	60.10%
Online tutoring	51.94%	52.49%	54.81%	43.78%
Micro-lecture	39.72%	41.02%	38.13%	39.57%
Recorded web courses	28.48%	31.16%	23.22%	32.67%
One-to-one live class	27.18%	32.89%	22.44%	21.38%
Self-learning based on resources	14.22%	12.69%	15.06%	16.73%
Course content				
School subject	80.18%	73.43%	85.95%	87.61%
Ability training	62.05%	69.61%	56.50%	51.37%

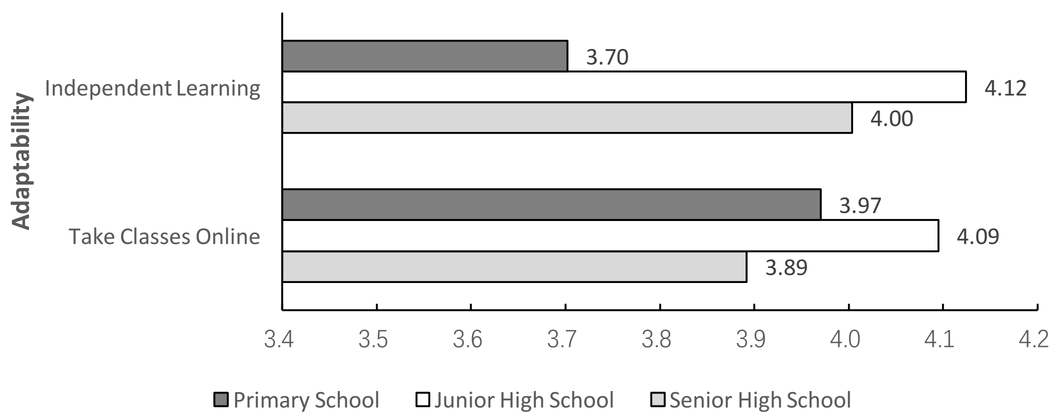
Online Learning Experience of Students

Online Learning Adaptability

In this part, a 5-point scale was conducted to measure the adaptability, which included two dimensions: adaptation to online classes and adaptation to self-regulated learning (Figure 3). The results revealed that the overall adaptability of students to online learning was good, with all scores around 4. In terms of different grades, junior high school students had the highest score. While senior high school students had better adaptability than primary school students in the aspect of self-regulated learning, the adaptability to online classes was just the opposite.

Figure 3

Online Learning Adaptability



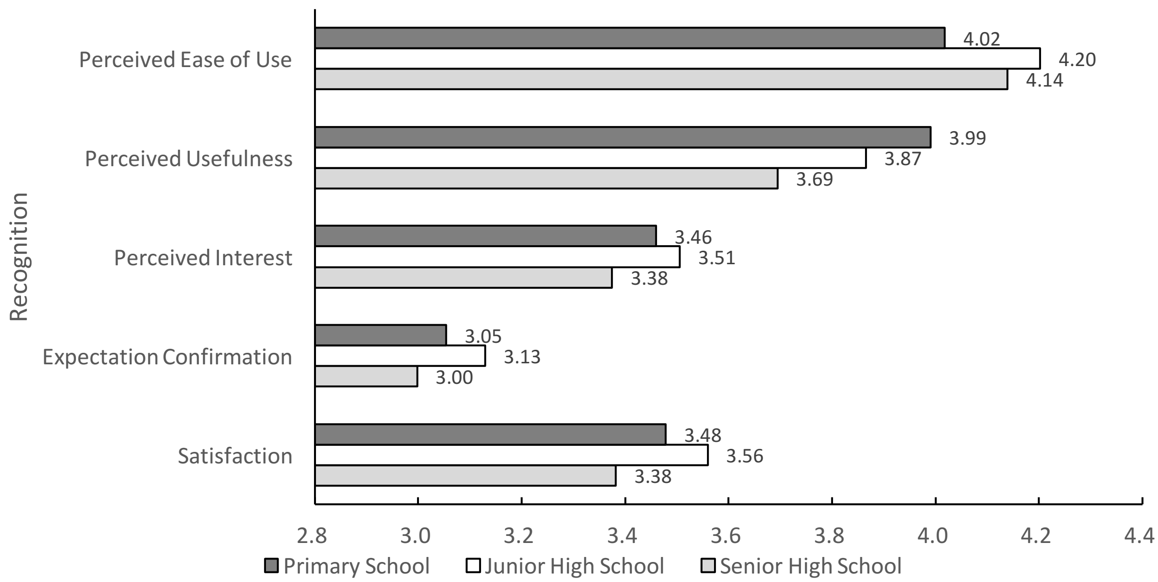
Online Learning Recognition

In this part, students' recognition of online learning includes five dimensions: perceived ease of use, perceived usefulness, perceived interest, expectation confirmation, and satisfaction. Perceived ease of use refers to the students' perceptions of how easy it is to use an online learning platform; perceived usefulness is the degree to which students believe, subjectively and objectively, that online learning is effective; perceived interest refers to students' interest in online learning; expectation confirmation refers to reaching students' expectations of online learning achievement during actual learning; and satisfaction refers to students' perceptions of their self-experiences and overall recognition of online learning after participating. The survey was still conducted on a five-point scale (Figure 4).

The results suggest that there was a big difference among the five dimensions. The highest were the perceived ease of use and perceived usefulness. The second were intermediate on satisfaction and perceived interest, and the lowest was expectation confirmation. This result indicated that students felt that there was a gap between the effect of online learning and their expectations. There were also differences in different grades. Junior high school students had better recognition than primary school students or senior high school students.

Figure 4

Online Learning Recognition



Online Learning Difficulties

In this study, students were asked to rank the online learning difficulties they encountered (Table 5). The difficulties centred around the lack of communication, the difficulty of concentrating on classes, and the lack of initiative in learning. And in terms of preparation for learning, there were mostly issues with the network and the learning environment. The variances in the difficulties faced by the students were small with regard to the different grades, but there were differences in the greatest difficulties. The biggest learning difficulty for primary and junior high school students was the lack of communication, and for senior high school students, it was the difficulty of concentrating.

Table 5

Online Learning Difficulties

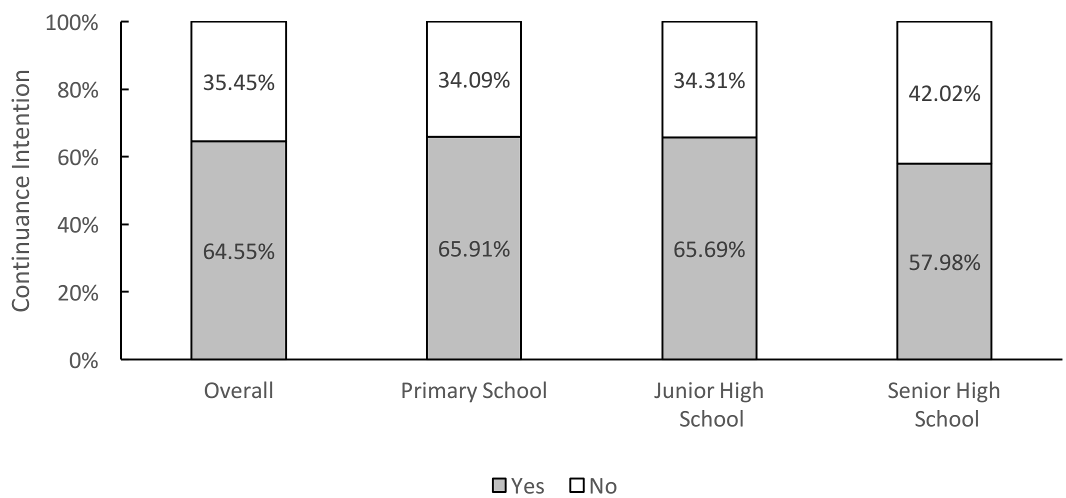
Dimension	Primary school	Junior high school	Senior high school
Lack of communication	5.54	4.73	4.58
Concentration	4.30	4.13	5.22
Network	3.12	4.34	4.04
Lack of initiative in learning	2.96	1.33	1.50
Noisy environment	1.72	2.28	2.47

Continuance Intention to Online Learning

As shown in Figure 5, 64.55% of students were willing to continue to participate in online learning after COVID-19. However, the number of students wanting to continue learning online tended to decrease as the grade rose. It was found that students were willing to continue to participate in online learning for three main reasons: the convenience of online learning, the opportunity to learn content that they were interested in, and the possibility to improve scores. The major reasons for their reluctance to continue the online learning were the lack of communication with teachers, lack of self-regulated learning abilities, and uninterested in online courses. In addition, a small number of students stressed technical problems with the network and equipment, as well as the damage to their eyes caused by electronics, as reasons for their unwillingness.

Figure 5

Online Learning Continuance Intention



To further investigate the factors affecting students' continuance intention, this research specified independent variables: demographic characteristics, online learning experience, online learning environment, online learning situations, self-regulated learning, online learning adaptability, perceived ease of use, perceived usefulness, perceived interest, expectation confirmation, satisfaction, and online learning difficulties (Table 6). The dependent variable was continuance intention to online learning. The coefficient of determination (R^2) of the regression model was 0.154, indicating that these variables together explain 15.4% of the variance. Demographic characteristics, device and network affordances, and online learning experience all had a positive effect on continuance intention, whereas learning difficulties had a negative influence.

In terms of demographic characteristics, gender, school grade, ethnicity, location, and learning experience all had significant effects on students' continuance intention to online learning. Students with a male gender, senior grade, Han nationality, in urban areas, and with online learning experience had higher intentions and a better online learning experience. Both devices and network affordances had a significant impact on continuance intention. In particular, students who used a computer or tablet and had better Internet access were more likely to continue learning online. In terms of the learning situation, the better the student's online learning situation and experience, the higher the student's willingness to stay engaged. Specifically, students who were more adaptable to learning, had a stronger interest in learning, and had higher confirmation expectations and satisfaction, were more inclined to continue online learning. In terms of learning difficulties, there was a negative correlation between learning difficulties and the intention of continuing online learning. Students who encountered four barriers (lack of equipment, poor Internet access, lack of interest, and difficulty in concentrating) were less likely to continue to participate.

Table 6

Analysis of Factors Influencing Online Learning Continuance Intention

Variable	*B*	*SE*	β	*t*	*p*
Constant	1.852	0.022		83.277	0.000
Personal background					
Gender	-0.049	0.004	-0.051	-13.011	0.000
Grade	0.03	0.003	0.046	9.295	0.000
Ethnicity	-0.015	0.006	-0.009	-2.316	0.021
Location	-0.007	0.002	-0.014	-3.568	0.000
Learning preparation					
Previous experience	0.113	0.004	0.117	29.671	0.000
Device type	0.017	0.005	0.017	3.596	0.000
Network condition	0.032	0.004	0.031	7.821	0.000
Learning situation					
Punctuality	0.018	0.003	0.028	5.203	0.000
Activity	0.01	0.004	0.017	2.766	0.006
Concentration	0.015	0.004	0.028	4.103	0.000
Homework	0.017	0.004	0.028	4.407	0.000

Variable	*B*	*SE*	β	*t*	*p*
Learning experience					
Perceived ease of use	0.008	0.003	0.014	2.452	0.014
Perceived usefulness	0.015	0.003	0.03	5.421	0.000
Adaptability	0.027	0.004	0.048	7.208	0.000
Perceived interest	0.082	0.003	0.176	26.027	0.000
Expectation confirmation	0.028	0.003	0.069	10.302	0.000
Satisfaction	0.029	0.003	0.059	8.229	0.000
Learning difficulty					
Device	-0.006	0.001	-0.033	-4.847	0.000
Network	-0.004	0.001	-0.017	-3.431	0.001
Interest	-0.014	0.001	-0.067	-11.375	0.000
Concentration	-0.002	0.001	-0.012	-2.376	0.018

Note. R=0.389, R^2=0.154. Adjusted R^2=0.154.

Discussion

Students have relatively high adaptability and recognition to online learning, especially in terms of perceived ease of use and perceived usefulness, and over 60% of students have continuance intention to online learning. On the one hand, related to the students' experience of online learning, the findings of this study showed that more than 40% of students have previous experience of online learning, which lays a good foundation for students to quickly adapt to long-term online learning. On the other hand, it is also related to the achievements of the construction of basic education informatization in China over the past decade. Since 2010, China's education informatization has made considerable progress (Zhang & Wang, 2019). Bottom-up innovation in education informatization has become the norm, with MOOC, micro-lecture, flipped classroom, and maker-based becoming hot spots in education informatization. This trend has also enabled teachers to improve their IT application ability and realize the transformation from "knowing how to use IT" to "knowing how to use IT for teaching". To a certain extent, this ensured the smooth implementation of online teaching during the epidemic. In addition, many schools placed great emphasis on home-school cooperation (Zheng & Wan, 2020).

Teachers and parents worked closely together to support and monitor students' home learning. All of these contributed to the effect of online learning, allowing students to adapt quickly.

Students have some learning difficulties in the process of online learning, including the lack of interaction, difficulty of concentrating, and the lack of learning initiative**.** On the one hand, some difficulties are related to the characteristics of online learning. In online learning, teachers and students are relatively separated in time or space. Self-regulated learning is the main form of learning, supplemented by teachers' aid; the teaching and learning behaviours are linked through various educational technologies and media resources (Ding, 2000). Teachers and students can only communicate through online platforms, yet separated by a screen, teacher-student interactions are vulnerable to network instability. Also, many teachers lack experience and preparation for teaching online. They do not place enough emphasis on interaction or even know how to design interactive activities, which leads to a lack of student interaction with teachers.

On the other hand, students are not prepared for self-regulated learning. Primary and high school students are still young. They usually perform well under the requirements of their teachers and the supervision of their parents and are able to complete their online learning tasks well. However, when given more autonomy, they do not perform as well. For instance, they are easily distracted by their surroundings and the various messages on electronic screens in class, making it difficult to concentrate on their learning. They also lack planning and reflection on their study, resulting in less initiative in learning.

There are significant differences in online learning between students of different grades. Junior high school students performed better than primary and senior high school students, as evidenced by being relatively more engaged in online classes and self-regulated learning and having a higher recognition of online learning. The main reasons for this difference are the psychological attributes, learning characteristics, and the academic strength of different students. Compared to primary school students' strong learning dependency and unstable and unsustainable attention (C.I. Wang, 2019), high school students begin to strengthen their self-concept and form a perception of learning (X.G. Wang, 2010), and their internal motivation to learn is enhanced, making them better able to self-manage the process of online learning. With moderate academic pressure, junior high school students can accept online learning to a greater extent and experience it with an open mind, eventually gaining a higher recognition of online learning. In the case of senior high school students, although they have stronger self-regulated learning abilities, they face more learning difficulties and academic pressure. The sudden arrival of online learning broke their original study habits and plans. Their adaptability to online classes was the worst of the three grades, and their participation and performance in online courses was also weaker.

Suggestions

It is necessary to summarize the experience of online learning during COVID-19, integrate the educational resources generated in this period, and improve the resource service system for basic education to guarantee blended learning in the post-epidemic era. Online education practices across China during COVID-19 pushed the reform of teaching modes. As a result, a new ecology of two-way integration between online education and school education is taking shape, showing a form of large-scale social collaboration (Yu et al., 2020). Every province in China developed a series of classrooms in the air to ensure the smooth development of online education, which rapidly gathered a large number of online resources. For example, the Education Bureau of Jiangsu Province organized the recording of online course resources covering 12 grades in primary and high schools; Guangxi Province developed more than 200 online free courses; and the Beijing Municipal Education Commission accumulated more than 1,000 quality courses online. How can these resources be integrated and applied to curriculum teaching after the end of the epidemic? Exploring a hybrid teaching model based on online resources should be the focus of education informatization reform.

Resources, as the core content of digital transformation in education, have become a key element in driving systemic change in education. The structural lack of resources in this epidemic period is highlighted by the low usage of existing resources by teachers (Zhao & Jiang, 2020). This is partly because the content and type of resources cannot meet individualized teaching needs. It is also because the interconnection between resource platforms at all levels is not deep enough, and there is no mechanism for sharing quality resources between localities. Therefore, on the one hand, there is a need to strengthen the construction and service capacity of high-quality resources, especially the ability training courses and cognitive tools. On the other hand, it is necessary to integrate various resource platforms at all levels and to clarify the functions of different resource platforms. For example, the national platform provides basic resources, which are mainly used to meet the basic needs of teachers and students. Enterprise platforms provide market-oriented resources to meet personalized learning needs. Also, school-level platforms self-supply school-based resources to support teachers and students in their educational activities (Ke et al., 2018).

It is important to promote reform of the classroom teaching modes and strengthen the cultivation of self-regulated learning ability for students in the class. The effects of online learning are directly related to students' self-regulated learning abilities, which is an important component of lifelong learning. This study found that students did not perform well in self-regulated learning during the epidemic, and this was one of the reasons for their poor learning outcomes. The Outline of Basic Education Curriculum Reform (for Trial Implementation) issued by China's Ministry of Education clearly states the development of students' subject consciousness and their ability to learn independently as one of the goals of the new curriculum reform. Therefore, taking advantage of online teaching, schools should integrate the cultivation of self-regulated learning abilities into their daily teaching. For example, teachers can use various tactics and tools prior to teaching the course content to help students make learning plans and rationalize their learning time. After teaching, teachers can guide students to reflect on their learning outcomes in a timely manner to develop their planning and evaluation skills. During the teaching process, teachers can utilize teaching strategies to design learning activities, provide scaffolding to motivate students to learn, lead them to think positively, enhance cooperation and express their opinions, and equip them with the right learning methods so that they can develop the ability to control and regulate their learning.

Making teachers' information literacy and online teaching skills the focus of teacher capacity enhancement in the post-epidemic era. Teachers, as the main subjects of the "suspension of school without suspending learning" practice, have experienced the change from face-to-face teaching to online teaching. It has been proven that teachers' information literacy and online teaching skills directly impact the effect of online education. The training of teaching skills in basic education has been mostly oriented towards face-to-face teaching and less towards online teaching. With the further development of education informatization, the ability to teach online will become one of the basic abilities of teachers in the "Internet+" era. To improve online teaching ability, first, teachers should focus on strengthening their understanding of the law of online teaching and mastering the capacity to choose the appropriate teaching mode according to different situations. Further, teachers should pay attention to information literacy development, be able to adapt to new technologies actively, and try to use new technologies in teaching. Finally, teachers should attach importance to improving their competence in instructional design. On the one hand, the focus of lesson preparation should be changed from studying the content to studying students' characteristics and designing teaching activities and interactions. Teachers should plan interesting activities based on the psychological and learning characteristics of students at different ages and guide them to actively participate in class. In addition, teachers should actively communicate with students after class to understand their needs and give them personalized guidance. On the other hand, teachers should shift from the traditional teaching model to a resource-based blended teaching model. Not only should face-to-face teaching be blended with online teaching but teaching and tutoring should also be combined to create a truly highly engaging and personalized learning experience for students (Feng et al., 2020).

References

Ding, X. F. (2000). A new definition of distance education, distance teaching and distance learning: Discussion on the basic concepts of distance education and open learning (3). *China Educational Technology, 7*, 47-49. https://kns.cnki.net/kcms/detail/detail.aspx?FileName=ZDJY200007024&DbName=CJFQ2000

Feng, X. Y., Wang, R. X., Cao, J. T., & Huang, L. Y. (2020). Trinity of educational supply-side reform in the era of "Internet+". *E-Education Research*, *41*(4), 42-47. https://doi.org/10.13811/j.cnki.eer.2020.04.006

Ke, Q. C., Wang, P. L., & Zhang, J. Q. (2018). Supply model, classification framework and developmental strategies of digital education resources. *E-Education Research, 39*(3), 68-74. https://doi.org/10.13811/j.cnki.eer.2018.03.011

Ministry of Education of the People's Republic of China. (2001). *Notice of the Ministry of education on printing and distributing the outline of basic education curriculum reform (for Trial Implementation)*. http://www.moe.gov.cn/srcsite/A26/jcj_kcjcgh/200106/t20010608_167343.html

Wang, C. F. (2019). An analysis of the psychological characteristics of primary school students. *Proceedings of the 2019 Conference on Innovative Research on Quality Education in Primary and Middle schools*. Beijing, China: Research Center for basic education curriculum reform of the Ministry of Education, 76. https://doi.org/10.26914/c.cnkihy.2019.012722

Wang, D. D., Wang, H. B., Zhang, W., Wang, H. R., & Shen, X. P. (2020). Research on online teaching in the period of "suspending classes without stopping learning"—based on 33,240 online surveys across the country. *Modern Educational Technology*, *30*(3), 12-18. https://kns.cnki.net/kcms/detail/detail.aspx?FileName=XJJS202003003&DbName=CJFQ2020

Wang, J. X., Cui, Y. P., & Yan, Y. T. (2020). Analysis on effect and potential influencing factors of massive online education practice during the COVD-19: a case of Xiaogan, Hubei Province. *E-Education Research*, *41*(6), 5-11. https://doi.org/10.13811/j.cnki.eer.2020.06.001

Wang, X. G. (2010). Analysis and guidance on the psychological characteristics of middle school students. *New West, 2*, 183-184. https://doi.org/10.3969/j.issn.1009-8607-B.2010.02.140

Yu, S. Q., Wang, D., & Wang, Q. (2020). Reform of large-scale socialized collaborative educational services. *E- Education Research*, *41*(4), 5-12. https://doi.org/10.13811/j.cnki.eer.2020.04.001

Zhang, L. G., & Wang, W. H. (2019). Education Informatization in China: scientific connotation, stage characteristics and evolutionary logic. *Contemporary Teacher Education*, *12*(1), 30-31. https://doi.org/10.16222/j.cnki.cte.2019.01.004

Zhao, H., & Jiang, F. (2020). An analysis on new model of educational resource construction in the era of "Internet+". *E- Education Research*, *41*(7), 48-49. https://doi.org/10.13811/j.cnki.eer.2020.07.007

Zheng, X. D., & Wan, K. (2020). Implementation logic, content and suggestions of home-school partnerships in large-scale K12 online teaching. *China Educational Technology, 4*, 16-20. https://doi.org/10.3969/j.issn.1006-9860.2020.04.006

Authors

Jiaju He holds a Bachelor of Education and is a postgraduate student of Distance Education in the Faculty of Education at Beijing Normal University, China. His research interests include Internet education, lifelong learning, ICT in education, and learning analytics. He has several educational research internship experiences in educational technology companies. Email: 320000309@qq.com

Hong Zhao, Associate Professor, Master's Supervisor in the Faculty of Education at Beijing Normal University, China. She is mainly engaged in the study of online learning and cognitive development research, with a focus on the study of learners' characteristics and ability training. Email: zhaohong@bnu.edu.cn

Fei Jiang holds a Master of Education from the Faculty of Education, Beijing Normal University, China. Her research interest is teaching and learning in online education. She has published several papers related to online learning and continuing education and has participated in the editing of teaching material. Email: 739802719@qq.com

CJLT RCAT
Canadian Journal of Learning and Technology
La Revue canadienne de l'apprentissage et de la technologie

Volume 48 (4) Special Issue 2022

It's Happy Hour Somewhere: Videoconferencing Guidelines for Traversing Time and Space

C'est l'happy hour quelque part: directives de vidéoconférence pour traverser le temps et l'espace

Agnieszka (Aga) Palalas*, Athabasca University, Canada*
Rebecca E. Heiser*, Athabasca University, Canada*
Ashley Gollert*, Athabasca University, Canada*

Abstract

Time seems to be moving at lightning speed with busyness unsustainably being "celebrated" and not allowing for sufficiently deep interaction with learning content, others, and the experience of which we are part, including our interactions in videoconferencing sessions. One benefit of videoconferencing is that it can address time and distance boundaries. With this advantage also comes a challenge - the pressures of time and time not being used purposefully often negatively impact the online learning experience and the digital wellness of its participants. Considering that, the reported study inquired: what are the videoconferencing guidelines in relation to temporal space to support digital wellness in online learning in higher education? Drawing on a systematic review of the relevant literature of the last decade, temporal guidelines have been distilled to promote the design of videoconferencing-based learning that is conducive to successful learning while maintaining digital well-being. The article organizes the literature review findings according to the categories identified through the secondary data analysis of its three preceding studies. Based upon 42 articles that met the inclusion and exclusion criteria in the first phase of the research design, we negotiated and determined thirteen temporal guideline themes described as time management, essentialism, purposefulness, agility, social presence, attention, inclusion, cooperation, respect, technology preparedness, creativity, evaluation, and safety. Further research is recommended to explore the various aspects of design in more depth and tackle the less frequently addressed themes of creativity, evaluation, and safety, focusing on pedagogy and human-centred approaches.

Keywords: Videoconferencing; Digital wellness; Time; Guidelines; Instructional design

Résumé

Le temps semble s'écouler à la vitesse de l'éclair, avec la saturation des tâches étant "célébrée" de manière insoutenable et ne permettant pas une interaction suffisamment profonde avec le contenu de l'apprentissage, les autres et l'expérience dont nous faisons partie, y compris nos interactions dans les sessions de vidéoconférence. L'un des avantages de la vidéoconférence est qu'elle permet de s'affranchir des limites de temps et de distance. Cet avantage s'accompagne également d'un défi : les contraintes de temps et le temps qui n'est pas utilisé de manière réfléchie ont souvent un impact négatif sur l'expérience d'apprentissage en ligne et le bien-être numérique de ses participants. Compte tenu de ce qui précède, cette étude a examiné : quelles sont les lignes directrices en matière de vidéoconférence par rapport à l'espace temporel pour soutenir le bien-être numérique dans l'apprentissage en ligne dans l'enseignement supérieur ? En s'appuyant sur un examen systématique de la littérature pertinente de la dernière décennie, des lignes directrices temporelles ont été distillées pour promouvoir la conception de l'apprentissage par vidéoconférence qui est propice à un apprentissage réussi tout en maintenant le bien-être numérique. L'article organise les résultats de la révision de la littérature en fonction des catégories identifiées par l'analyse des données secondaires de ses trois études précédentes. Sur la base de 42 articles qui ont satisfait aux critères d'inclusion et d'exclusion dans la première phase de la conception de la recherche, nous avons négocié et déterminé treize thèmes de lignes directrices temporelles décrits comme la gestion du temps, l'essentialisme, le caractère intentionnel, l'agilité, la présence sociale, l'attention, l'inclusion, la coopération, le respect, la préparation technologique, la créativité, l'évaluation et la sécurité. Il est recommandé de mener d'autres recherches afin d'explorer plus en profondeur les différents aspects de la conception et de s'attaquer aux thèmes moins fréquemment abordés que sont la créativité, l'évaluation et la sécurité, en se concentrant sur la pédagogie et les approches centrées sur l'humain.

Mots-clés : Vidéoconférence ; bien-être numérique ; temps ; directives ; conception pédagogique

Introduction

Online educators who utilize videoconferencing solutions must embrace two realities. The first is a sense of urgency over time - a limited commodity that is precious in online learning due to its socio-emotional and pedagogical value. The second is savouring the timelessness of learning and reflection. Berg and Seeber (2016) suggest that educators should "…advocate deliberation over acceleration. We need time to think, and so do our students. Time for reflection and open-ended inquiry is not a luxury but is crucial to what we do" (p. x). Time is a critical learning design component to activate a learning environment that supports and sustains learner cooperation, integration, and a sense of belonging to achieve academic success (Meeuwisse et al., 2010). Moments spent together engaging in videoconferencing platforms (e.g., Microsoft Teams, Blackboard, and Zoom) can reduce the distance between online learners and instructors by offering a dedicated space for real-time interaction and communication. While the need to cultivate deep thought and human interaction collides with the culture of speed, researchers agree that "time constraints are barriers to integrating critical thinking skill" (Snyder & Snyder, 2008, p. 93). In addition, the pressures to learn and teach *efficiently* with declining resources of time have been found to be detrimental to participants' well-being (Buckholdt & Miller, 2013).

The study reported herein addresses the need for guidelines to help online educators and instructional designers navigate the temporal requirements and pressures of videoconferencing. We asked: what are the videoconferencing guidelines in relation to temporal space to support digital wellness in online learning in higher education? This article proposes time-related guidelines distilled from a larger survey we conducted on videoconferencing learning design. Due to the extensiveness of the multiphase research, this report concentrates on recommendations regarding the usage of time in videoconferencing. By employing a systematic review of the relevant literature of the last decade, the article organizes its findings according to the thematic categories identified through the secondary data analysis of its four preceding studies (Palalas, 2018; Palalas et al., 2018, 2020) which explored learning design that promotes holistic digital wellness of online graduate students.

Digital Context

Although videoconferencing and other digital technologies enable us to be better connected than ever in the virtual space, unbalanced and often excessive interactions with digital devices might deter successful learning experiences and outcomes. The present-day online learning context is threatened by digital distraction caused by information overload targeting our attentional capacity through multiple digital channels (Levy, 2016; Palalas, 2018; Pegrum & Palalas, 2021). These distractions are coupled with a digital disorder, i.e., misinformation, disinformation, and fake news (Pegrum & Palalas, 2021; Wardle & Derakhshan, 2017), as well as digital disconnection "with digital users being superficially present online but in actuality disconnected from the self …and, relatedly, from others" (Pegrum & Palalas, 2021, p. 3).

Consequently, the pre-existing challenges of online education, related to its physical and emotional distance (Moore, 2013) as well as technological and pedagogical challenges, have now been magnified, potentially leading to fragmented attention and chronic stress negatively impacting physical and mental health issues (Couros, 2019; Dobelli, 2020; Wenger, 2019). Additional challenges that may negatively impact student well-being and mental health include such polarized experiences as boredom versus overwhelm, anxiety related to limited access and ability to participate in online learning versus students feeling excessively connected, mood changes due to curriculum requirements and design perceived by students as ineffective or as overly ambitious, stress over online exams and assessments, lack of online netiquette, and many other related concerns (Irawan et al., 2020; Mamun et al., 2020; Moawad, 2020; Saxena, 2020).

The critical stressors identified by recent research involve technical difficulties, diminished learner capability and confidence levels, time challenges, distractions, frustration, anxiety and confusion, lack of emotional and physical attention, and limited digital literacy skills (Saxena, 2020). Building on earlier research by Palalas (2018) and Palalas et al. (2018, 2020), which indicates that online graduate students mention a variety of difficulties with attention in the context of digital learning; they mention being perpetually digitally overwhelmed, experiencing persistent distraction, and experiencing chronic distractibility, caused by information overload and by multiple digital spaces concurrently demanding their attention. Consequential multitasking may lead to addictive behaviours, depression, anxiety, and other mental health issues, as well as reduced empathy or prosocial attitudes (Bonnardel et al., 2018; Melo et al., 2020). An increasing number of studies also warn of the distracting effects of screens, particularly mobile screens, combined with social media and broader Internet access in learning and other contexts (Felisoni & Godoi, 2018; Ward et al., 2017; Whelan et al., 2020), which may also be correlated with depression and anxiety (Page, 2019).

The Palalas (2018) and Palalas et al. (2018, 2020) study participants also list the following challenges experienced in online learning: the hyper personal dimension of digital communication; privacy and safety concerns; the feeling of isolation in the world of hyper connection; mental health and burnout; an ever-increasing pace; emotional and physical exhaustion and frustration having to do more in less time due to all the various demands coming from professional and personal lives, and resultant increasing pressures on their self-regulation and time management, just to mention the most glaring ones which impact the online learning experience and also the overall wellness of the participants. While appreciating the flexibility afforded by online learning, the students described their digital learning experience using the following phrases: “no time to think,” “no time off,” “expected to be working 24/7,” “need to produce quickly,” “sense of overload and confusion,” and “stressed by the always-on lifestyle and its requirements.” The glaring concerns related to the issue of time instigated the current study and search for more meaningful and healthy use of digital pedagogies and technologies in relation to temporal features/strategies in videoconferencing spaces.

Digital Wellness

Feedback from past studies (Palalas, 2018; Palalas et al., 2018, 2020) pointed to the significance of a whole-person approach to learning in the digital space, including the emotional, social, mental, spiritual, physical, and cognitive dimensions of online learning and their many constituents. The learners’ (and instructors’) holistic well-being, although attracting little attention prior to the lessons learned during the worldwide hastily migration of learning to remote delivery, has now concerned more learning designers (Joseph & Trinick, 2021) and educational policymakers around the globe (Higgins & Goodall, 2021) who seek to implement teaching and learning practices (content and facilitation) that contribute to the holistic wellness of learners, including their mental-physical health, rather than merely cognitive outcomes (albeit impacted by the learner’s overall well-being). We have adopted a related notion of Digital Wellness defined by the Digital Wellness Institute as “the optimum state of health and well-being that each individual using technology is capable of achieving” (Blankson & Hersher, 2021, p. 4).

Drawing on the Digital Flourishing® Wheel (Digital Wellness Institute, 2020), other similar frameworks that address digital users’ wellness, and the findings of the preceding studies (Palalas, 2018; Palalas et al., 2018, 2020), the following eight dimensions of digital wellness for online learners have been identified as essential: cognitive, social, emotional, spiritual, physical, digital identity, environmental, and productivity. They are considered holistically in our current study and addressed in the discussion of the findings.

Methods

Phased Qualitative Protocol

Our research is framed with a holistic lens aligned to digital wellness as defined above. In order to understand evidence-based approaches and distill guidelines for online distance learning educators and instructional designers using videoconferencing tools in higher education contexts, we used a phased research protocol. The first phase, i.e., the larger systematic review, was guided by the question: what are the guidelines for effective practice for learning designers with video conferencing in online higher education? In the second phase, we employed a secondary data analysis to explore the temporal aspects of videoconferencing and select the guidelines that promote participant well-being. This article reports on the second phase related to the use of time in videoconferencing to support successful learning and digital wellness in online learning in higher education.

Systematic Review

By using the preferred reporting items for systematic reviews and meta-analyses (PRISMA) to explore empirical research findings and address the primary research question (Moher et al., 2009; Zawacki-Richter et al., 2020), we were able to reduce bias and draw reliable conclusions for educators to implement video conferencing guidelines within their contexts and practice (Gopalakrishnan & Ganeshkumar, 2013). In this initial research phase, we utilized five databases, including Discover, Google Scholar, Science Direct, Springer, and Taylor and Francis, with a Boolean operator as a search strategy to evaluate peer-reviewed videoconferencing studies conducted in formal higher education settings and published in English between 2011 and 2021. Next, we used Rayyan, a software solution for systematic reviews (Ouzzani et al., 2016) to screen and negotiate meaning from 169 potential articles and synthesized 82 articles to inform explicit guidelines presented through the literature. Articles eligible for this study must include evidence-based guidelines from empirical studies regarding video conferencing tools employed in distance learning experiences in undergraduate and graduate contexts. Once the inclusion criteria were applied, we narrowed the results to 42 articles before proceeding to the second phase of the research.

Secondary Structural Analysis

Based on the preliminary findings of the systematic review, additional secondary data analysis was conducted using an inductive, structural coding strategy (Saldaña, 2016) to categorize temporal themes within the data corpus and inform video conferencing wellness guidelines for online distance learning stakeholders. We negotiated and determined 13 temporal themes (Table 1), which were selected based on the code book generated during the larger systematic review (i.e., the first phase); the descriptions of the codes were revised to reflect the focus on time. We then reread each article with video conferencing guidelines to identify the references accordingly.

Table 1

Themes of Temporal Space in Video Conferencing Guidelines

Theme	Description (*references to…*)
Time management	processes and strategies to organize, plan, or prepare for an optimal learning experience using video conferencing tools
Purposefulness	intentional pedagogical and technological design and strategy decisions
Social presence	social interaction activities, the degree of feeling authentic or the belief in intimacy and interpersonal engagement among participants in the video conference event
Attention	asynchronous supplementary supports and conditions as learning design and facilitation strategies to structure the learning experience during, before, and/or after the synchronous event to distribute learning, promote attentive engagement, focus concentration, and prioritize specific content and/or activities efficiently
Inclusion	providing equitable access, accessibility, and inclusive learning experiences for all participants
Cooperation	interactions among peers and the instructor to support engagement, cohesion, and structure
Agility	the instructor's ability to quickly and effectively maneuver, adjust, and facilitate an optimal learning experience for all learners, despite deficient conditions and factors
Respect	regarding participant needs or expectations, or consideration to participant perceptions and satisfaction
Technology preparedness	the intentional use of time to train and prepare instructors and students in the use of video conferencing technologies
Essentialism	learning and instructional design decisions to limit and/or prioritize content, structural and strategic elements and components to include what is meaningful and essential for successful learning processes and outcomes

Theme	Description (*references to…*)
Creativity	reconceptualizing the functionality of the video conferencing tool to create conditions for learning
Evaluation	efforts to support continuous improvement and reflective practice
Safety	privacy, security, and ethical considerations to ensure all participants feel confident and comfortable engaging in an authentic and protected learning environment

Findings

Based upon 42 articles that met the inclusion and exclusion criteria in the first phase of the research design, coding resulted in ten significant categories to address our research question. Additionally, *creativity*, *evaluation*, and *safety* codes were applied to the data corpus, but their count frequency was below 30 references which we deemed insignificant to report from this analysis phase. Table 2 demonstrates the total frequency counts by code reference across the 42 articles and articulates the code definitions that three coders used to iterate and negotiate meaning from the findings and recommendations of peer-reviewed empirical studies.

Table 2

Frequency of Codes in Video Conferencing Guidelines

Code reference	Reference frequency
Time management	117
Purposefulness	96
Social presence	74
Attention	69
Inclusion	54
Cooperation	50
Agility	49
Respect	47
Technology preparedness	45
Essentialism	34

The research team documented over 635 references with a significant count (n=117) of explicit references to *time management* guidelines. Time management references ranged from less than desirable outcomes, such as "valuable teaching time was lost on something that could have been planned prior to the session" (Divanoglou et al., 2018), to preventative practices including, "Participants should have opportunities before the session to test and play with their earphones, microphones and the features of the online tools. It is advisable to schedule 10–15 minutes extra at the start of a session to sort out any technical issues" (Vuuren & Freisleben, 2020, p. 274). Scholars cited specific recommendations on the length and frequency of video conferencing sessions; for example,

> Results suggest something of a 'tipping point' of three to four sessions per 12-week semester course, with a maximum of 1½ hours per session. Beyond this, it is likely that use would be considered intrusive and could detract from student independence. This particularly applies to international students contending with time zones. (Falloon, 2012, p. 121)

We identified references (n=96) to *purposefulness* described as the intentional pedagogical and technological design and strategy decisions. Since distance education is often defined as the "planned learning that normally occurs in a different place from teaching, requiring special techniques of course design and instruction, communication through various technologies, and special organizational and administrative arrangements" (Moore & Kearsley, 2011, p. 2), it's not surprising that the purposefulness code emerged so frequently. Articles that included references to purposefulness provided learning design guidance such as, "During the meeting, instructors should… have music playing as students enter; this helps with audio setup… Display a set of instructions and meeting agenda that each student will see upon joining the session" (Wang et al., 2013, p. 25).

In addition, many articles referred to *social presence* (n=74) with effective practices to "allow time for student attendees to introduce themselves, including names, current roles in education, and what they hope to gain from this webinar" (Gautreau et al., 2020, p. 7). In particular, Falloon (2012) reports that "Some students commented that much relationship formation groundwork had been done prior to the [video conference] classroom sessions and that they served more to consolidate or evolve existing relationships to a different level" (p. 113). Additionally, scholars Wang and Chen (2012) recommend,

> that text chat plays a supplementary role to oral and visual interaction, in order to bring a sense of immediacy and authenticity to collaborative learning in a cyber face-to-face classroom. Thus, collaborative task design needs to ensure a proper balance between text chat, and oral and visual interaction. (p. 324)

The *attention* code (n= 69) draws upon references to blending the affordances of synchronous and asynchronous modalities to create a learning experience structure that focuses learner attention and concentration on the video conferencing event. One example of the attention reference draws from the work of scholars Vuuren and Freisleben (2020), in which they state,

> The funnelling of attention from various physical spaces through the screen into the online room can invite a unique kind of intensity that is not derived from the perception of bodies, but from the world's one is looking into, and the curiosities found there. The editing out of all which is not relevant to the interaction by the frame of the computer window and the simultaneous lure of what is off-screen does create an intensity that, if maintained, brings a level and depth of focus that can be highly beneficial for learning, while at the same time it remains fragile and susceptible to fracturing. To create and maintain this focus while minimizing the possibility of fracturing, the facilitator must work with the other forms of boundary creation to contain the engagement. (p. 275)

Additionally, the attention code references challenges and pressures to facilitate and learn in a video conferencing environment, such as "There's no time to waste, you just do have to move on ... I find I need to concentrate and really keep things together, and it's a different sort of environment in that way, it's quite intense" (Cornelius, 2014, p. 265).

We employed the *inclusion* code (n=54) to identify specific references to the affordances of video conferencing learning experiences as an extension to a virtual environment that holds time and space between human proximity. In one example, Tonsmann (2014) describes "an important and unexpected benefit of this teaching modality, one that could be aptly employed for teaching mobility-challenged individuals such as handicapped persons and wounded veterans" (p. 58). Additionally, Falloon (2012) expands the context and design considerations for international student participation in a video conference environment and reports that different time zones presented an additional logistical challenge for international students, with some in Canada and the Middle East needing to work late into the night or early morning to participate… Interestingly, none of them saw this as a major issue for the number of times the classrooms were used but commented that if more frequent use was required, their thinking might change. As one put it, "as long as we know, we opt in on that basis. We have the choice— it's our responsibility" (p. 120).

Of similar frequency and aligned closely to the s*ocial presence* code (n=74), we defined *cooperation* (n=50) as references to interactions among peers and the instructor to support engagement, cohesion, and structure. An example delineated from the secondary data analysis describes the challenges of building cooperation in video conferencing experiences, "having limited capacity for only one speaker to talk at a time, discussions take a longer time and also the participants may have to repeat their utterances many times if two people talk at the same time" (Gedera, 2014, p. 98).

We discovered a theme focused on the facilitator's ability to quickly and effectively maneuver, adjust, and facilitate an optimal learning experience for all learners, despite deficient conditions and factors. The *agility* code (n=49) was utilized to describe the role of the instructor in a video conferencing environment. Farooq and Matteson (2016) claim that "in addition to facilitation and scaffolding purposeful critical reflection, also included monitoring the ongoing technical concerns during the session" (p. 277). Additionally, Singhal (2020) suggests, "The key is to be flexible and improvise if the technology does not align with the intended goals... The instructor has to be vigilant" (p. 2713).

An emerging theme was identified as *respect* (n= 47), in which we coded references to guidance on the regard participant needs or expectations or consideration to participant perceptions and satisfaction. In one example, Alhlak et al. (2012) state, "time management creates a professional respectful impression" (p. 108), whereas Kan (2011) reported challenges with students participating across international time zones, "my undergraduates became antsy about prolonging dialoguing on difficult issues as it neared dinnertime, while HNU participants had difficulties remaining attentive as the body clocks for these early risers were not charged with adequate vibes at daybreak" (p. 13).

In addition to *purposefulness* (n=96) and *agility* (n=49) codes, we negotiated a theme on *technology preparedness* (n=45) to describe the intentional use of time to train and prepare instructors and students for the use of video conferencing technologies. Kobayashi (2015) explicitly calls on instructors and instructional designers to "[t]ake time to train students on how to use the system and expect that some students may need additional support" (p. 8). Also, Divanoglou et al. (2018) caution that without ample technology preparedness, "technical problems encroached on teaching time, which impeded their learning" (p. 94) and "valuable teaching time was lost because teachers didn't know tech and didn't use it right" (p. 99).

Essentialism (n=34) was codified for instructors and instructional designers to consider "the potential for less content to be covered" (Bensafa, 2014, p. 93) and to "place time restrictions on each task in order to encourage productivity" (Bower et al., 2015, p. 10). The essentialism code is exemplified by Mpungose (2021) who found,

> that time is a critical element in offering effective online lectures; lecturers outlined that lectures of 1-h duration are more productive than those of 2 to 3 hours because students do not get bored and are left still wanting to learn more. This suggests that online lectures need different time schedules, and it should become the duty of the university management to work on time schedules that can maintain the effective use of Zoom for e-learning. (p. 11)

Three additional inductive structural codes were developed for the secondary analysis, including creativity, evaluation, and safety, as identified in Table 1. However, the frequency of the counts for these codes was insignificant, which is revisited in the following discussion.

Temporal Guidelines

As evidenced by the results, temporal space delineations in video conferencing studies frequently provide time management and purposefulness recommendations to guide instructors and instructional designers who employ videoconferencing technologies to facilitate learning. However, present technologies continue to carry significant challenges to digital wellness when designing instruction in a synchronous context. It is prudent to draw attention to the implications and recommendations for future research in implementing the distilled temporal guidelines to support digital wellness within learning, design, and instructional processes. We recognize that digital wellness is not explicitly considered within the literature. Therefore, we have embedded a human dimension for the wellness of students in online learning by summarizing recommendations into two categories of guidelines, planning and implementation, as outlined in the following sections.

Planning Guidelines

The temporal aspect that attracted the most attention pertains to time management. When scheduling a videoconference session across borders and multiple time zones, the facilitator must consider the time of day the videoconference takes place (Kan, 2011; Mpungose, 2021; Saitta et al., 2011). Videoconferencing sessions should be scheduled when learners can participate "with reciprocal enthusiasm" (Kan, 2011, p. 13), recognizing the mental and physical exhaustion that might result from the participants spending significant amounts of time on alternate digital commitments. An important consideration during the initial planning and implementation of a videoconferencing session is its length of time. Scholars suggest that the optimal duration of a session ranges from 30 to 90 minutes (Alhlak et al., 2012; Correia et al., 2020; Hoyt et al., 2013; Mpungose, 2021; Smith et al., 2020). Engaging in shorter sessions lessens the strain on learners and allows for more concentrated dialogue to evolve. Our exploration of the literature has determined that shorter sessions are more productive than those of a longer duration. Smith et al. (2020) reported that students often multitask during long synchronous sessions and that "if the professor used solely lecture as the pedagogical approach, there was very little that could keep the students focused the whole time" (p. 204). Shorter sessions lead to greater engagement and enthusiasm for future learning. In interactive sessions whereby learners share their thoughts and opinions on a topic, the instructor must consider the appropriate amount of time for each activity; a maximum of 15 to 20 minutes of discussion before including another learner-centered activity is ideal for maintaining interest and structure during the session (Richardson et al., 2012; Singhal, 2020; Smith et al., 2020). During these shorter sessions, consideration must be given to how breaks are implemented. A short period of instruction or dialogue, approximately 30 to 45 minutes in length, followed by a 10 to 15-minute break, allows learners to step away and return ready to engage in the lesson (Alhlak et al., 2012). These built-in interactions maintain learners' engagement for the duration of the session and encourage further participation through additional platforms.

Implementation Guidelines

Participation is a key component of successful video conferencing sessions, and learners should come prepared to engage in collaborative discussions and activities. At the same time, to address the digital wellness of learners, instructors are encouraged to implement impromptu accommodations, such as recording lectures or reducing the amount of screen time to address the limitations to participation that may unexpectedly present themselves. Offering learners the opportunity to revisit the material later leads to more efficient and effective learning (Foronda & Lippincott, 2014; Hussein, 2016; Lewis et al., 2020). This type of adjustment is expressed across the reviewed literature and encapsulated through the agility code.

Learners and instructors must plan out the content and processes concerning an individual's ability to interpret and apply information. Providing students with learning materials at least 24 hours in advance of the scheduled session helps them familiarize themselves with and reflect on the material being discussed (Alhlak et al., 2012; Hoyt et al., 2013; Lewis et al., 2020). When presenting information for the first time during a session, students do not have adequate time to understand and reflect on the material. However, when provided at least 24 hours in advance, student attentiveness and participation are better supported as they have time to develop their understanding, leading to a more concentrated and thought-provoking discussion of the topics at hand (Smith et al., 2020). Preparedness, which also encompasses the concept of technical preparedness, is essential in creating a well-balanced synchronous space that respects all learners' cognitive abilities and skills. It is imperative to consider technology preparedness when planning a synchronous videoconferencing session. Each synchronous platform displays unique features that instructors and students must be able to utilize before, during, and after a synchronous session. Technology preparedness includes training instructors and students to be familiar and confident with the videoconferencing technology before engaging in the formal learning session (Gautreau et al., 2020; Kobayashi, 2015); this may also be addressed by opening the session approximately 10 to 15 minutes early to allow testing technical equipment and troubleshooting any potential issues (Foronda & Lippincott, 2014; Vuuren & Freisleben, 2020). Additionally, an emotional sense of feeling prepared removes barriers to allow all participants in the videoconferencing environment to collaborate and align with the collective learning goal. Instructors and learners will then enter the learning space feeling prepared, safe, and ready to participate in the learning community.

Digital wellness can be further increased through conversation with others, enabling intimate connections within the learning community (Almendingen et al., 2021), thereby leveraging social presence. Learners might be more willing to engage in an in-depth conversation when social connections have been previously established. During the initial 15 to 20 minutes of a new session, offer students the opportunity to connect socially with other members of their learning community through a short pre-instructional conversation session to engage with other students (Gautreau et al., 2020). These short introductory sessions allow the facilitator to build a sense of community throughout the cohort, leading to a safe and respectful learning environment (Hoyt et al., 2013; Kan, 2011). The more time participants spend together synchronously in videoconference events, the more they feel connected (Joseph & Trinick, 2021). Based upon the greater sense of connection, awareness of each individual's social capacity could be optimized and lead to the creation of a collective digital identity.

Implications for Future Research

Although we know from previous research that facilitators should reflect on their instructional design decisions and determine appropriate pedagogical strategies to create the conditions for effective learning (Çakıroğlu et al., 2016; Laurillard, 2013). Most literature in our analysis did not call attention to the intersection of quality and effective usage of time. Our research found few references regarding *evaluation* as a procedural tool to collect information for continuous improvement and reflective practice. While Gedera (2014) mentions the importance of taking the time for a 10 to 15-minute debriefing activity for student reflection and decompression, we did not find any other explicit mentions of evaluating the usefulness of the hours and minutes spent on digital screens. With a much larger volume of time spent online rather than offline, facilitators and instructional designers need to reflect on the effectiveness of the time spent on individual platforms (Tarus, 2021).

Likewise, with a primary focus on learner-centred design, it's surprising to see the lack of *safety* references in video conferencing studies in higher educational contexts. As Correia et al. (2020) defines, "safety, which includes privacy and security, is also a major concern when using videoconferencing systems for online learning and teaching because of learners' privacy" (p. 444). This is particularly important, given ethical review board guidelines, the Federal privacy laws, and localized institutional data privacy protocols operationalized in higher education contexts worldwide. Within our analysis, we recognized the value of references to privacy, security, and ethical considerations to ensure all participants feel confident and comfortable to engage in an authentic and protected learning environment in both phases of our study. As detailed by Vuuren and Freisleben (2020), creating boundaries to protect sensitive information that may be inadvertently displayed is essential for creating a safe learning environment. The authors state "These boundaries are physical and temporal, as well as conceptual and emotional. Participant safety relies heavily on the facilitator's ability to create and maintain these boundaries, especially in the absence of four physical walls" (Vuuren & Freisleben, 2020, p. 247). Further research is required to explore these issues in more depth as education is rapidly migrating in online spaces.

Conclusion

From the temporal perspective, the videoconferencing space offers numerous affordances that, if leveraged appropriately, can promote a rich, inclusive learning experience that respects the digital wellness needs of learners and allows them to participate fully in technology-enabled education while maintaining the optimum state of their well-being. With digital technologies dynamically advancing in the background regardless of the educational field, the online learning design focus should shift to human-centered pedagogical strategies that transverse a specific videoconferencing platform or other learning technologies, including learning management systems (LMS). As observed by Schwier (2021), "Universities struggle with which LMS they should adopt, but too few conversations are held about how courses are designed and delivered…" (p. ix). They raise a timely question highlighting the lack of progress in distance education theory: "In a learning ecology that invites innovation and change, and apparently demands it, why do organizations apparently hold so tenaciously to fairly traditional and conservative approaches to distance education?" (p. ix). Indeed, based on the evidence collected during our research, insufficient attention has been given to innovative approaches to learning in the videoconferencing space to prevent ever-increasing digital hazards, such as zoom fatigue (Bailenson, 2021) or digital burnout (Bozkurt & Sharma, 2020). We have proposed a set of videoconferencing guidelines to serve as a springboard to such conversation and further empirical research. The aspect of time deserves attention as this resource has become an "endangered" commodity in our fast-paced reality.

For many of us, including the students who spoke about the pressures of time negatively impacting their online learning experience, time seems to be moving at lightning speed with busyness unsustainably being "celebrated," and not allowing for sufficiently deep interaction with the learning content, with others, with the experience of which we are part. In future studies, the perception of time and our relationship to time could be viewed from a novel perspective and with regard to Nakamura and Csikszentmihalyi's (2014) observation that when we are "in flow" and "the passage of time, a basic parameter of experience, becomes distorted because attention is so fully focused elsewhere" (p. 92), we can experience a sense of timelessness while genuinely and wholly engaged in the activity at hand. "Slow approaches" to teaching and learning should also be considered (Berg & Seeber, 2016; Boulous Walker, 2017; Frith, 2020) to further inform the design of effective videoconferencing-based learning going forward.

References

Alhlak, B. A., Ramakrisnan, P., Hameed, Z. S., & Mohseni, H. R. (2012). Video Conference: Integrated Tool for Identifying CSF in Education Development in UiTM. Procedia - *Social and Behavioral Sciences*, *67*, 102–113. https://doi.org/10.1016/j.sbspro.2012.11.311

Almendingen, K., Morseth, M. S., Gjølstad, E., Brevik, A., & Tørris, C. (2021). Student's experiences with online teaching following COVID-19 lockdown: A mixed-methods explorative study. *Plos One*, *16*(8), 1–16. https://doi.org/10.1371/journal.pone.0250378

Bailenson, J. N. (2021). Nonverbal overload: A theoretical argument for the causes of Zoom fatigue. *Technology, Mind, and Behavior*, *2*(1). https://psycnet.apa.org/doi/10.1037/tmb0000030

Bensafa, A. (2014). Using video conferences for ESP postgraduate students: An example of distance learning at the University of Tlemcen/Algeria. *Revista Românească pentru Educație Multidimensională*, *6*(2), 79-95. https://doi.org/10.18662/rrem%2F2014.0602.06

Berg, M., & Seeber, B. K. (2016). *The slow professor: Challenging the culture of speed in the academy*. University of Toronto Press. https://doi.org/10.1111/fcsr.12321

Blankson, A., & Hersher, N. (2021). *Digital Wellness: Your playbook for thriving in the remote work era.* Wiley Beyond. https://universityservices.wiley.com/wp-content/uploads/2021/01/2021-DigitalWellness-eBook.pdf

Bonnardel, V., Biddington, T., May, B., Jones, R., & Roffey, S. (2018). Toward the implementation of contemplative practices in higher education. *Journal of Perspectives in Applied Academic Practice*, *6*(3), 3-13. https://doi.org/10.14297/JPAAP.V6I3.362

Boulous Walker, M. (2017). *Slow philosophy: Reading against the institution*. Bloomsbury Academic.

Bower, M., Dalgarno, B., Kennedy, G. E., Lee, M. J., & Kenney, J. (2015). Design and implementation factors in blended synchronous learning environments: Outcomes from a cross-case analysis. *Computers & Education, 86*, 1-17. https://doi.org/10.1016/J.COMPEDU.2015.03.006

Bozkurt, A., & Sharma, R. C. (2020). Education in normal, new normal, and next normal: Observations from the past, insights from the present and projections for the future. *Asian Journal of Distance Education*, *15*(2). http://dx.doi.org/10.5281/zenodo.4362664

Buckholdt, D. R., & Miller, G. E. (Eds.). (2013). *Faculty stress*. Routledge.

Çakıroğlu, U., Kokoç, M., Kol, E., & Turan, E. (2016). Exploring Teaching Programming Online through Web Conferencing System: The Lens of Activity Theory. *Journal of Educational Technology & Society*, *19*(4), 126–139. http://www.jstor.org/stable/jeductechsoci.19.4.126

Cornelius, S. (2014). Facilitating in a demanding environment: Experiences of teaching in virtual classrooms using web conferencing. *British Journal of Educational Technology*, *45*(2), 260-271. https://doi.org/10.1111/bjet.12016

Correia, A.-P., Liu, C., & Xu, F. (2020). Evaluating videoconferencing systems for the quality of the educational experience. *Distance Education*, *41*(4), 429–452. https://doi.org/10.1080/01587919.2020.1821607

Couros, A. (2019). #77 – Attention literacy with Alec Couros. [Interview by W. Richardson.] *Modern Learners*. https://modernlearners.com/77-alec-couros/

Digital Wellness Institute (2020). https://www.digitalwellnessinstitute.com/

Divanoglou, A., Chance-Larsen, K., Fleming, J., & Wolfe, M. (2018). Physiotherapy Student Perspectives on Synchronous Dual-Campus Learning and Teaching. *Australasian Journal of Educational Technology*, *34*(3), 88–104.

Dobelli, R. (2020). *Stop reading the news: A manifesto for a happier, calmer and wiser life.* [Trans. C. Waight.] London: Sceptre.

Falloon, G. (2012). Inside the virtual classroom: Student perspectives on affordances and limitations. *Journal of Open, Flexible and Distance Learning*, *16*(1), 108–126. https://doi.org/10.3316/informit.384108311721545

Felisoni, D. D., & Godoi, A. S. (2018). Cell phone usage and academic performance: An experiment. *Computers & Education*, *117*, 175-187. https://doi.org/10.1016/j.compedu.2017.10.006

Foronda, C., & Lippincott, C. (2014). Graduate nursing students' experience with synchronous, interactive videoconferencing within online courses. *Quarterly Review of Distance Education*, *15*(2), 1.

Frith, U. (2020). Fast lane to slow science. *Trends in Cognitive Sciences*, *24*(1), 1-2. https://doi.org/10.1016/j.tics.2019.10.007

Gautreau, C., Dailey, K., & Evans, L. (2020). Building Virtual Bridges: Engaging Online Learners through an Interactive Webinar Series. *Journal of Educators Online*, *17*(2).

Gedera, D. S. P. (2014). Students' Experiences of Learning in a Virtual Classroom. *International Journal of Education and Development Using Information and Communication Technology*, *10*(4), 93–101.

Gopalakrishnan, S., & Ganeshkumar, P. (2013). Systematic reviews and meta-analysis: Understanding the best evidence in primary healthcare. *Journal of Family Medicine and Primary Care, 2*(1), 9-14. https://doi.org/10.4103/2249-4863.109934

Higgins, J., & Goodall, S. (2021). Transforming the well-being focus in education: A document analysis of policy in Aotearoa New Zealand. *International Journal of Qualitative Studies on Health and Well-being*, *16*(1), 1879370. https://doi.org/10.1080/17482631.2021.1879370

Hoyt, J., Howell, S., Lindeman, S., & Smith, M. (2013). The Feasibility of Offering Videoconferencing Courses: Quality Issues and Lessons Learned. *Journal of Continuing Higher Education*, *61*(2), 94–103. https://doi.org/10.1080/07377363.2013.796255

Hussein, H. E. M. (2016). The Effect of Blackboard Collaborate-Based Instruction on Pre-Service Teachers' Achievement in the EFL Teaching Methods Course at Faculties of Education for Girls. *English Language Teaching*, *9*(3), 49–67. http://dx.doi.org/10.5539/elt.v9n3p49

Irawan, A. W., Dwisona, D., & Lestari, M. (2020). Psychological impacts of students on online learning during the pandemic COVID-19. KONSELI: *Jurnal Bimbingan dan Konseling (E-Journal)*, *7*(1), 53-60. https://doi.org/10.24042/kons.v7i1.6389

Joseph, D., & Trinick, R. (2021). "Staying Apart Yet Keeping Together": Challenges and Opportunities of Teaching During COVID-19 Across the Tasman. *New Zealand Journal of Educational Studies*, *56*(2), 209–226. https://doi.org/10.1007/s40841-021-00211-6

Kan, K. H. (2011). Meeting Face to Face= Seeing Eye to Eye?: Interglobal Dialogue via Videoconference. *International Journal of Education and the Arts*, *12*(10). https://www.learntechlib.org/p/52011/

Kobayashi, M. (2015). Students' Evaluation of Google Hangouts through a Cross-Cultural Group Discussion Activity. *Turkish Online Journal of Distance Education*, *16*(2), 28–39. http://dx.doi.org/10.17718/tojde.98784

Laurillard, D. (2013). *Teaching as a design science: Building pedagogical patterns for learning and technology*. Routledge.

Lewis, P. J., Catazano, T. M., Davis, L. P., & Jordan, S. G. (2020). Web-based Conferencing: What Radiology Educators Need to Know. *Academic Radiology*, *27*(3), 447–454. https://doi.org/10.1016/j.acra.2019.05.017

Mamun, M. A., Chandrima, R. M., & Griffiths, M. D. (2020). Mother and son suicide pact due to COVID-19-related online learning issues in Bangladesh: An unusual case report. *International Journal of Mental Health and Addiction*, 1-4.

Meeuwisse, M., Severiens, S. E., & Born, M. P. (2010). Learning environment, interaction, sense of belonging and study success in ethnically diverse student groups. *Research in Higher Education*, *51*(6), 528-545. https://doi.org/10.1007/s11162-010-9168-1

Melo, C., Madariaga, L., Nussbaum, M., Heller, R., Bennett, S., Tsai, C.-C., & van Braak, J. (2020). Editorial: Educational technology and addictions. *Computers & Education*, 145. https://doi.org/10.1016/j.compedu.2019.103730

Moawad, R. A. (2020). Online learning during the COVID-19 Pandemic and Academic Stress in University Students. *Revista Românească pentru Educație Multidimensională*, *12*(1 Sup2), 100-107. https://doi.org/10.18662/rrem%2F12.1sup2%2F252

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS medicine*, *6*(7), e1000097. https://doi.org/10.1016/j.jclinepi.2009.06.005

Moore, M. G. (2013). *The theory of transactional distance. In Handbook of distance education* (pp. 84-103). Routledge.

Moore, M. G., & Kearsley, G. (2011). *Distance education: A systems view of online learning*. Boston, MA: Cengage Learning.

Mpungose, C. B. (2021). Lecturers' reflections on use of Zoom video conferencing technology for e-learning at a South African university in the context of coronavirus. *African Identities*, 1-17. http://dx.doi.org/10.1080/14725843.2021.1902268

Nakamura, J., & Csikszentmihalyi, M. (2014). *The concept of flow. In Flow and the foundations of positive psychology* (pp. 239-263). Springer, Dordrecht.

Ouzzani, M., Hammady, H., Fedorowicz, Z. (2016). Rayyan—a web and mobile app for systematic reviews. *Systematic Reviews* 5, 210. https://doi.org/10.1186/s13643-016-0384-4

Page, K. (2019). *College mindfulness training: Reducing student life stress and improving academic performance*. Routledge.

Palalas, A. (2018). Mindfulness in mobile and ubiquitous learning: Harnessing the power of attention. In S. Yu, M. Ally, & A. Tsinakos (Eds.), *Mobile and ubiquitous learning: An international handbook* (pp. 19-44). Singapore: Springer. https://doi.org/10.1007/978-981-10-6144-8_2

Palalas, A. (2019). Mindfulness for human-centred digital learning. *Argentinian Journal of Applied Linguistics*, *7*(2), 110-125.

Palalas, A., Mavraki, A., Drampala, K., & Krassa, A. (2018, April). Mindfulness in online and blended learning: Collective autoethnography. In A. Palalas, H. Norman, & P. Pawluk (Eds.), *Blended learning in the age of social change and innovation: Proceedings of the 3rd World Conference on Blended Learning* (pp. 84-96). Greece: International Association for Blended Learning.

Palalas, A., Mavraki, A., Drampala, K., Krassa, A., & Karakanta, C. (2020). Mindfulness Practices in Online Learning: Supporting Learner Self-Regulation. *The Journal of Contemplative Inquiry*, *7*(1).

Pegrum, M., & Palalas, A. (2021). Attentional Literacy as a New Literacy: Helping Students Deal with Digital Disarray. *Canadian Journal of Learning and Technology*, *47*(2). https://doi.org/10.21432/cjlt28037

Richardson, J. C., Fox, W. S., & Lehman, J. D. (2012). Scenarios for Teacher Education Programs. *Tech Trends*, *56*(5), 17–24. https://doi.org/10.1007/s11528-012-0595-z

Saitta, E. K. H., Bovvdon, M. A., & Geiger, C. L. (2011). Incorporating Service-Learning, Technology, and Research Supportive Teaching Techniques into the University Chemistry Classroom. *Journal of Science Education and Technology*, *20*(6), 790–795.

Saldaña, J. (2016). *The coding manual for qualitative researchers*. Sage.

Saxena, K. (2020). *Coronavirus accelerates pace of digital education in India*. EDII Institutional Repository.

Schwier, R. A. (2021). Foreword: An attendant posture. In Martha F. Cleveland-Innes and D. Randy Garrison (Eds), *An Introduction to Distance Education: Understanding Teaching and Learning in a New Era*. (2nd ed., pp. vii-x). Routledge.

Singhal, M. (2020). Facilitating Virtual Medicinal Chemistry Active Learning Assignments Using Advanced Zoom Features during COVID-19 Campus Closure. *Journal of Chemical Education*. https://doi.org/10.1021/acs.jchemed.0c00675

Smith, J., Schreder, K., & Porter, L. (2020). Are They Paying Attention, or Are They Shoe-Shopping? Evidence from Online Learning. *International Journal of Multidisciplinary Perspectives in Higher Education*, *5*(1), 200–209.

Snyder, L. G., & Snyder, M. J. (2008). Teaching critical thinking and problem solving skills. *The Journal of Research in Business Education*, *50*(2), 90.

Tarus, L. (2021). Digital Well-Being between Lifestyles in Limited Pandemic Conditions and the Varied Offer of Social Platforms. *Revista Universitara de Sociologie*, *17*(2), 234–244.

Tonsmann, G. (2014). A Study of the Effectiveness of Blackboard Collaborate for Conducting Synchronous Courses at Multiple Locations. *InSight: A Journal of Scholarly Teaching*, *9*, 54–63. http://dx.doi.org/10.46504/09201404to

Vuuren, P. J. van, & Freisleben, C. F. (2020). How to catch a flying pig: Facilitating embodiment work in online rooms. Research in Drama Education: *The Journal of Applied Theatre and Performance*, *25*(2), 268–285. https://doi.org/10.1080/13569783.2020.1730169

Wang, C. X., Jaeger, D., Liu, J., Guo, X., & Xie, N. (2013). Using Synchronous Technology to Enrich Student Learning. *Tech Trends, 57*, 20-25. https://doi.org/10.1007/s11528-012-0626-9

Wang, Y., & Chen, N.-S. (2012). The collaborative language learning attributes of cyber face-to- face interaction: The perspectives of the learner. *Interactive Learning Environments*, *20*(4), 311–330. https://doi.org/10.1080/10494821003769081

Ward, A. F., Duke, K., Gneezy, A., & Bos, M. W. (2017). Brain drain: The mere presence of one's own smartphone reduces available cognitive capacity. *Journal of the Association for Consumer Research*, *2*(2), 140-154. https://doi.org/10.1086/691462

Wardle, C., & Derakhshan, H. (2017, Sep. 27). Information disorder: Toward an interdisciplinary framework for research and policy making. Strasbourg: *Council of Europe*. https://edoc.coe.int/en/media-freedom/7495-information-disorder-toward-an-interdisciplinary-framework-for-research-and-policy-making.html

Wenger, C. I. (2019). Teaching attention literacy: A case for mindfulness in the composition classroom. *Pedagogy: Critical Approaches to Teaching Literature, Language, Composition, and Culture*, *19*(1), 53-78. https://doi.org/10.1215/15314200-7173752

Whelan, E., Najmul Islam, A. K. M., & Brooks, S. (2020). Applying the SOBC paradigm to explain how social media overload affects academic performance. *Computers & Education*, *143*. https://doi.org/10.1016/j.compedu.2019.103692

Zawacki-Richter, O., Kerres, M., Bedenlier, S., Bond, M., & Buntins, K. (Eds.) (2020). *Systematic reviews in educational research: Methodology, perspectives and application*. Springer Nature.

Authors

Dr. Agnieszka (Aga) Palalas is Associate Professor and EdD Program Director in the Open, Digital, and Distance Education Program at Athabasca University, Canada. Drawing from over 25 years of experience as a face-to-face and online educator, instructional designer, and an IT programmer, combined with her two-decade-long mindfulness practice, Aga researches and designs digital learning for the whole person, which nourishes the intellect, body, and mind of the individual and the community. Email: agapalalas@athabascau.ca

Rebecca E. Heiser serves as the Interviews Editor with the American Journal of Distance Education and acts as the student advisory board member with ICDE's Global Doctoral Consortium. Her research interests include quality dimensions in transnational distance education, internationalization strategies, and systems perspectives of open, online and distance education. Email: rheiser1@athabasca.edu

Ashley Gollert is a member of the Faculty of Education with the University of Lethbridge, Canada. Her main teaching focus is with assessment and evaluation. Ashley's current research focuses on integrating Indigenous ways of knowing and doing in the Canadian K-12 classroom environment. Email: agollert1@athabasca.edu

CJLT RCAT
Canadian Journal of Learning and Technology
La Revue canadienne de l'apprentissage et de la technologie

Volume 48 (4) Special Issue 2022

The Interconnectivity of Heutagogy and Education 4.0 in Higher Online Education

L'interconnectivité de l'héutagogie et de l'éducation 4.0 dans l'enseignement supérieur en ligne

Jeanne Kim, *Athabasca University, Canada*

Abstract

Industry 4.0 advancements in technology are creating a dynamic and fast changing world that affects how we live and work. Educators need to rethink existing teaching approaches to better prepare learners for future careers that Industry 4.0 will create. The World Economic Forum defined a new education model, called Education 4.0, which contains eight major changes to redefine learning in the new economy. Heutagogy, or self-determined learning, is an approach that promotes critical thinking, social-emotional skills, and life-long learning. These skills are necessary for Education 4.0. The purpose of this paper is to recommend the principles of heutagogy as an effective teaching and learning approach to meet the needs of Education 4.0. The approach of the study examines existing literature on Education 4.0 and heutagogy. A conceptual model that interconnects heutagogy to the four learning principles of Education 4.0 will be offered as a key finding to answer the research question: How does heutagogy in higher online education meet the needs of Education 4.0? The paper provides a base for further research and discussion into how heutagogy and other approaches can support the needs of Education 4.0 to prepare learners for a changing world.

Keywords: Education 4.0; Heutagogy; Higher online education; Industry 4.0; Lifelong learning

Résumé

Les progrès technologiques de l'industrie 4.0 créent un monde dynamique et en rapide évolution qui affecte notre façon de vivre et de travailler. Les éducateurs doivent repenser les approches pédagogiques existantes afin de mieux préparer les apprenants aux futures carrières que l'industrie 4.0 créera. Le Forum économique mondial a défini un nouveau modèle d'éducation, appelé Éducation 4.0, qui contient huit changements majeurs pour redéfinir l'apprentissage dans la nouvelle économie. L'heutagogie, ou apprentissage autodéterminé, est une approche qui favorise la pensée critique, les compétences socioémotionnelles et l'apprentissage tout au long de la vie. Ces compétences sont nécessaires à l'éducation 4.0. L'objectif de cet article est de recommander des principes de l'heutagogie comme une approche d'enseignement et d'apprentissage efficace pour répondre aux besoins de l'éducation 4.0. L'approche de l'étude consiste à examiner la littérature existante sur l'éducation 4.0 et l'heutagogie. Un modèle conceptuel qui relie l'heutagogie aux quatre principes d'apprentissage de l'éducation 4.0 sera proposé comme résultat principal pour répondre à la question de recherche : comment l'heutagogie dans l'enseignement supérieur en ligne répond-elle aux besoins de l'éducation 4.0 ? Ce document fournit une base pour des recherches et des discussions plus approfondies sur la façon dont l'heutagogie et d'autres approches peuvent répondre aux besoins de l'éducation 4.0 afin de préparer les apprenants à un monde en évolution.

Mots-clés : éducation 4.0 ; heutagogie ; enseignement supérieur en ligne ; industrie 4.0 ; apprentissage tout au long de la vie

Introduction

Technological and global change in our social, economic, and work environments affects how we teach and how we learn. One of the drivers of change is technological disruption. The fourth industrial revolution, or Industry 4.0, is a technological revolution that will disrupt and transform how we live, work, and relate to each other (Schwab, 2016). Klaus Schwab, Founder and Executive Chairman for the World Economic Forum (WEF) professed that technology has made it possible for people to access the digital world through new products and services, such as “ordering a cab, booking a flight, buying a product, making a payment, listening to music, watching a film, or playing a game” (Schwab, 2016). These advancements in technology and globalization changed whole industries (ride sharing such as Uber changed the taxi industry) which triggered the increasing need for new skills in current jobs and, at the same time, displaced certain jobs and created new ones (Zahidi, 2019). The World Economic Forum (2020) estimated that 65% of students currently in school will work in jobs that do not exist today, 47% of today’s jobs will be automated in the next 10 years, and beginning in 2020, more than 50% of the content in graduate degrees will no longer be relevant in 5 years. By the time we learn something, it quickly becomes outdated. Agonacs and Matos (2019) described the twenty-first century learning context:

> where the constantly changing workplace requires fast learners; where knowledge and skill acquisition has become increasingly the responsibility of the individual; where learning happens ubiquitously and non-linearly; where the Internet is a primary source of information; where an excess of information is at one’s disposal in a second; where most of the learning occurs through knowledge sharing; and where the role of the teacher or trainer has radically changed (p. 223).

Educators need to rethink existing teaching approaches to prepare students for future careers that Industry 4.0 will change and create. How we teach and how we learn needs to be “re-imagined for the emerging futures of work” (Hussin, 2018; Salmon, 2019) including both the alignment of technology and human teaching and learning. Education 4.0 is a revolution in education that responds to the changes born from Industry 4.0 (Abdullah et al., 2020; Hussin, 2018; JISC, 2019; Koul & Nayar, 2021, p. 99). Skills that are most valuable in an Industry 4.0 world are those that are human-centric such as leadership, social influence, emotional intelligence, collaboration, creativity, critical thinking, flexibility, and adaptation to change (Salmon, 2019; World Economic Forum, 2020).

Heutagogy, or self-determined learning, can provide a model of online learning and teaching in higher education that develops autonomous capabilities for learners to design and create their own learning paths based on their needs, while promoting a new era of life-long learning that is critical for a changing digital world (Agonacs & Matos, 2019; Blaschke, 2021; Hussin, 2018; Ishak & Mansor, 2020; Salmon, 2019). Learning is becoming more aligned with what we do rather than what we know, making traditional methods of disciplined-based knowledge inadequate to prepare learners to live and work in communities and workplaces (Davis & Hase, 2001). Adult learners and workers will expect flexible and agile learning experiences that will match the needs of the future (Blaschke, 2021; Salmon, 2019).

A gap in the literature on Education 4.0 was found regarding a lack of pedagogical approaches. Most of the literature that discussed Education 4.0 focused on the competencies, skills, and capabilities required to meet the disruptions caused by Industry 4.0 as well as emphasizing a need for changes in how we educate and how we learn. The WEF (2020) suggested that education systems must become innovative and offered five key innovation approaches: playful; experiential; computational; embodied; and multiliteracy. Fisk (2017) offered an approach developed by the Institute for the Future (2013) whereby they suggested traditional education needs to transform into learning flows where education becomes “embedded in everyday settings and interactions, distributed across a wide set of platforms and tools” (Institute for the Future, 2013). The purpose of this paper is an attempt to address the transformation of education by suggesting heutagogy as an effective teaching and learning approach to meet the needs of Education 4.0. Ashton and Newman (2006) assessed that heutagogy “reflects the changed world in which learning takes place and recognizes the complex array of skills required for today’s different kind of workplace” (p. 829). Thus, this review of the literature on Education 4.0 and heutagogy in higher online education is guided by the following research question: How does heutagogy in higher online education meet the needs of Education 4.0? A conceptual model that interconnects heutagogy to the learning principles of Education 4.0 will be offered as a key finding. This paper provides a base for further research and discussion into how heutagogy and other approaches can support the needs of Education 4.0 to prepare learners for a changing and constantly evolving world.

Literature Review

The Evolution of Education

Academic literature in the field of Education 4.0 is limited. Much of the research and information about Education 4.0 is found in reports, blogs, videos, and websites. Themes found in these resources vary in discussions about the evolution of education from Education 1.0 to Education 4.0 (Koul & Nayar, 2021; Salmon, 2017; Salmon, 2019), comparisons on the relationship between Industry 4.0 and education (Abdullah et al., 2020; Ally & Wark, 2020; Elayyan, 2021; Shahroom & Hussin, 2018; Xing & Marwala, 2017), and Education 4.0 frameworks that describe the future of education (Abdullah et al., 2020; Fisk, 2017; Koul & Nayar, 2021; World Economic Forum, 2020). A common theme of Education 4.0 found in the literature is that it is a response to global change that will impact jobs, businesses, governments, economies, culture, and education due to Industry 4.0 (Fisk, 2017; JISC, 2019; Koul & Nayar, 2021; Salmon, 2019; World Economic Forum, 2020).

Education 4.0 evolved from the models of Education 1.0 to Education 3.0 and has been described using Web 1.0 to Web 4.0 as a metaphor (Gernstein, 2014; Salmon, 2017; Salmon, 2019). Education 1.0 "is a type of essentialist, behaviourist education based on the three Rs", which stands for receiving, responding, and regurgitating (Gernstein, 2014, p. 84). According to Salmon (2019), Education 1.0 and Web 1.0 represented "transmissive" ways of learning and teaching. Education 2.0 evolved with Web 2.0 (also called the 'read-write' Web), which provided interaction, collaboration, and content creation (Salmon, 2019). Web 3.0, or the Semantic Web, provided education with "relevant, interactive and networked content that is freely and readily available and personalized, based on individual interests" (Gernstein, 2014, p. 89). Education 3.0 is, therefore, considered the digital and mobility era of education, transforming the role of the educator to include digital tools and applications (Harkins, 2008; Salmon, 2019). Enter Education 4.0 and Web 4.0 (the 'symbiotic Web'), a model of education where "students will expect, perhaps demand, learning experiences that reflect and enhance the way [to] live in the world" (Salmon, 2019, p. 102). In other words, the goal of Education 4.0 is to create a global education ecosystem, where the learner is at the core and empowered to create their own learning journey and their own knowledge (Koul & Nayar, 2021).

Education 4.0 Frameworks

There are two notable Education 4.0 frameworks found in the research conducted. The first is Peter Fisk's (2017) Nine Trends in Education 4.0. Fisk's (2017) vision of Education 4.0 "establishes a blueprint for the future of learning – lifelong learning – from childhood schooling to continuous learning in the workplace, to learning to play a better role in society" (para. 4). According to Fisk (2017), the process of learning will need to change and transform to something that is more personalized and collaborative. He identified nine trends that define Education 4.0 as shown in Table 1.

A second framework is offered by the WEF which defined the new education model Education 4.0, which aims to increase the quality and accessibility of learning through innovation, social mobility, and inclusion (World Economic Forum 2020). In their report, "Schools of the Future: Defining New Models of Education for the Fourth Industrial Revolution", they provide a framework outlining four foundational skills and four approaches to learning "that more closely mirror[s] the future of work, and that takes full advantage of the opportunities offered by new learning technologies" (p.6) as shown in Table 2.

Table 1

Nine Trends in Education 4.0

Trend	Brief description
Diverse time and place	Students need opportunities to learn anytime, anywhere
Personalized learning	Students learn at their own pace, taking on harder tasks after a certain mastery is achieved
Free choice	Students have a choice in how they want to learn
Project based	Students will adapt to applying skills in shorter terms to a variety of situations
Field experience	Students will be exposed to more hands-on, real-world opportunities i.e., internships
Data interpretation	Manual calculations will become irrelevant due to machines. Students will need to apply analysis and critical thinking skills to predict future trends
Exams will change completely	Students' knowledge will be assessed as they learn and demonstrate learnings through projects in the field
Student ownership	Students will become more dependent on their own learning
Peers and mentorship	Due to students' increased independence, mentoring will become fundamental to their success

Note. Adapted from Nine Trends in Education 4.0, by P. Fisk, 2017.

Table 2

The World Economic Forum Education 4.0 Framework

Foundational skills (content)	Approaches to learning (experiences)
Global citizenship skills	Personalized and self-paced learning
Innovation and creativity skills	Accessible and inclusive learning
Technology skills	Problem-based and collaborative learning
Interpersonal skills	Lifelong and student-driven learning

Note. Adapted from Schools of the Future: Defining New Models of Education for the Fourth Industrial Revolution, World Economic Forum, 2020, p. 7.

The focus of the WEF's framework is to prepare children for skills and knowledge that will be needed in an Industry 4.0 work world; however, the framework can be applied to adults entering higher education as well as workers who either need or want to upgrade their skills and knowledge as their work environments change. It is interesting to note that of the four skills identified by the WEF, only one referenced technology skills. Salmon (2019) identified this paradox where, although digital literacy and technological skills will be warranted to work and live in the new Industrial 4.0 era, the most valuable skills for the future will depend on the inherent human characteristics, such as "creativity, critical thinking, responsive communication, and out-and-out human collaboration" (p. 109). Another skill emphasized in the literature was the importance of lifelong learning (Ally & Wark, 2020; Koul & Nayar, 2021; World Economic Forum, 2020; Xing & Marwala, 2017). Lock et al. (2021) commented that "dynamic, complex societies now expect learning across one's lifetime" (p. 1648), which will require learner agency and interactive methods of teaching and learning.

Both frameworks share a few common principles: a focus on learner-centred ownership to create their own learning path that is lifelong; learning will shift from traditional and siloed competencies to experiential and project-based capabilities that focus on adaptability and agility; assessment will become more "authentic, meaningful, and reflective" (Salmon, 2019); and the role of the educator transitions to a mentor, where the curriculum is collaboratively designed with the student. This paper will focus on WEF's Education 4.0 model, which proposes a framework specifically designed to prepare learners for the Industry 4.0 work world.

Heutagogy

The Principles of Heutagogy

Heutagogy, also referred to as self-determined learning, was developed by Stewart Hase and Chris Kenyon in 2000 (Agonacs & Matos, 2019; Blaschke, 2012; Hase, 2014). It is a learning approach that places the "learner at the centre of the learning process" (Hase & Blaschke, 2021a, p. 13). In other words, the learner determines what and how to learn (Hase, 2014; Hase & Kenyon, 2000). Hase and Blaschke (2021a) provided a simplified list of principles fundamental to heutagogy. The first principle is *learner agency*, where the learner is at the centre deciding what and how to learn and how their learning should be assessed. *Self-efficacy and capability* refers to a learner's ability to know how to learn, which is dependent on "the learner's belief in his or her own abilities, and capability, which is the ability of the learner to demonstrate an acquired competency or skill in new and unique environments" (p. 14). *Metacognition and reflection* are concepts that go hand-in-hand. Metacognition is the process of learning by applying a double-loop method, which requires reflection, a critical learning skill that allows learners to synthesize what they have learned. *Non-linear learning* is the process whereby learners define and choose a variety of paths to learning and where the learner is responsible to choose what to learn and how to learn it. The last principle, *Learning how to learn*, is inherent within all four principles; nonetheless, it was deemed an essential principle by McAuliffe et al. (2009).

The Correlation of Learner Agency, Capability, and Lifelong Learning Skills

What is fundamental to self-determined learning hinges on learner agency, which is "the capacity of learners to take responsibility for and to direct and determine their own learning paths" (Hase & Blaschke, 2021b, p. 7). For learner agency to work, learners need to have a certain level of motivation and self-efficacy to define their learning path (Hase, 2014, p. 18). Hase (2014) recognized that a learner's agency "is something that is intrinsic to each individual person" (pp. 18-19) and is a culmination of a person's experiences, both past and present, providing learners with skills in both competence and capability.

It is important to highlight that heutagogy makes a distinction between competence and capability. While heutagogy recognizes competence as essential to being capable, it raises the importance of the capability to learn (Blaschke & Hase, 2015; Davis & Hase, 2001; Hase & Davis, 1999). Nagarajan and Prabhu (2015) defined competence as having skills, knowledge, and capacity to fulfill current needs, while capability focuses on the ability to develop and adapt to meet future needs. Capable people are more inclined to be creative, competent learners, prefer to work in teams, collaborate well, and have strong self-efficacy (Hase & Davis, 1999). Hase and Davis (1999) concluded that capable people experience richer learning experiences from those who only use competencies to learn (para 8).

Blaschke (2021) gathered capability skills that aligned with the principles of heutagogy found from three sources: "Future Skills: The Future of Learning and Higher Education" (Ehlers & Kellermann, 2019); "European Framework for the Digital Competence of Educators: DigCompEdu" (Redecker & Punie, 2017); and "LifeComp: The European Framework for Personal, Social and Learning to Learn Key Competence" (Sala et al., 2020), as shown in Table 3.

Table 3

Heutagogy Principles Aligned with Lifelong Learning Skills

Heutagogy principle	Lifelong learning skills
Learner agency	Active learning and learning strategies; autonomy; creativity; flexibility; leadership; personal agility; self-direction; self-initiative (intrinsic motivation); self-management; self-regulation
Self-efficacy and capability	Self-efficacy; tolerance for ambiguity
Reflection and meta-cognition	Ability to reflect; analytical thinking and innovation; complex problem-solving; critical thinking and analysis; ideation; reasoning; self-regulation; sense-making
Non-linear learning	Active learning and learning strategies; collaboration; cooperation and communication competence; digital literacy; technology use

Note. Adapted from Table 1. Heutagogy principles aligned with lifelong learning skills accessed from The Dynamic Mix of Heutagogy and Technology: Preparing Learners for Lifelong Learning by L.M. Blaschke, 2021, p. 1634.

The purview of each of the reports used by Blaschke (2021) are varied; however, all have one common theme: to identify key skills and competencies to work and live in a dynamic and changing world. The “European Framework for the Digital Competence of Educators: DigCompEdu” (Redecker & Punie, 2017) focused on identifying digital competencies for educators “to be able to effectively use digital technologies for teaching” (p. 15), while the “Future Skills: The Future of Learning and Higher Education” report takes a broader focus, which identified future skills that include individual development, instrumental, and social world/organization-related skills (Ehlers & Kellermann, 2019). Lastly, “LifeComp: The European Framework for Personal, Social and Learning to Learn Key Competence” focused on key competencies needed for lifelong learning and learning how to learn (Sala, et al., 2020). Blaschke (2021) concluded that heutagogy is an approach that can prepare students with lifelong learning skills to adapt to a changing workforce.

Heutagogy in Higher Online Education

Heutagogy has a natural place in higher online education because it shares “certain key attributes, such as learner autonomy and self-directedness, and has pedagogical roots in adult teaching and learning” (Blaschke, 2012, p. 57). Blaschke (2012) identified three specific common characteristics that both distance education and heutagogy share:

- Technology: Distance education considers implications of emerging technology on distance education theory and practice. The relationship with heutagogy is that it is considered a potential theory as a way to integrate emerging technologies in distance education.
- Profile of the distance education learner: Distance education has, traditionally, been designed for the experienced adult working learner. Historically, distance education practices have been strongly influenced by Knowles’ (1975) andragogy theory, which heutagogy is an extension of.
- Learner autonomy: Distance education supports a level of autonomy, a skill that is pivotal in heutagogical teaching and learning approaches.

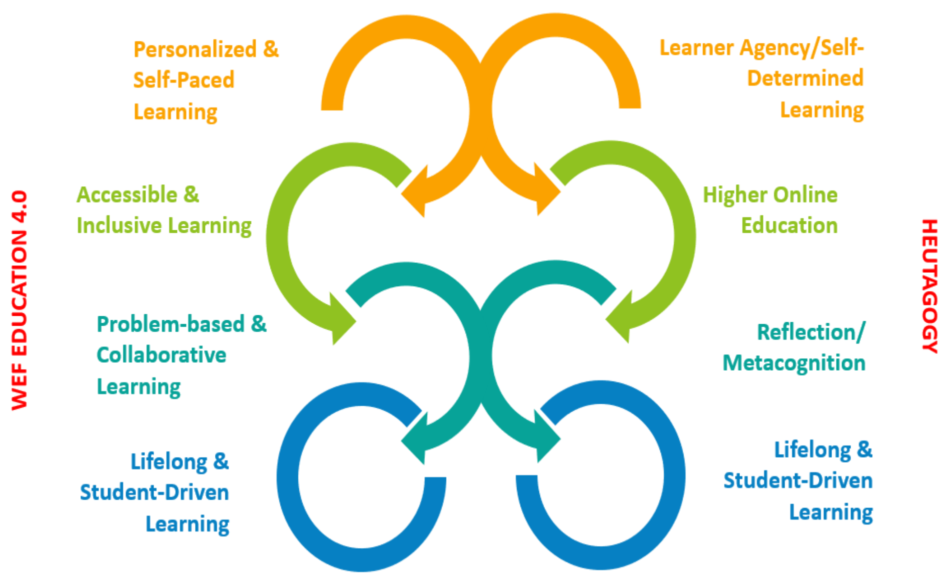
Online learning technologies, such as the use of e-portfolios, mobile learning, and social media, provide increased opportunities in learner agency, self-efficacy and capability, metacognition, non-linear learning, and learning how to learn (Blaschke, 2021). Further to this, Lock, et al.’s (2021) Delphi study on technology-enabled lifelong learning revealed a correlation between technology, online and blended higher education, and heutagogy. One of their conclusions indicated that heutagogy’s principles can occur in blended and online learning environments (Lock, et al., 2021).

Key Findings

This article aimed to address a gap in the literature on pedagogical approaches to applying the Education 4.0 framework by recommending heutagogy to address changes in how we live, learn, and work. The review of the literature on Education 4.0 and the principles of heutagogy revealed similarities in their approach to learning. Although the review was not exhaustive, it highlighted an interconnection between the two learning approaches as shown in Figure 1. As discussed in the literature review, Education 4.0 and heutagogy places the learner at the centre of the learning journey. This, unto itself, connects Education 4.0 to heutagogy. This concept led the author to investigate how heutagogy in higher online education can meet the needs of Education 4.0. Examples from qualitative studies are offered that demonstrate the application of the principles of heutagogy that align with Education 4.0's framework. Figure 1 illustrates how heutagogy's main principles correlate to WEF's Education 4.0 learning approaches.

Figure 1

The Interconnectivity of Heutagogy and WEF's Education 4.0



Personalized/Self-Paced Learning and Learner Agency/Self-Determined Learning

The World Economic Forum (2020) described personalized and self-paced learning as students designing their individual learning paths, gauging their own progression based on skill proficiency, and having flexible learning environments. Similarly, learner agency and self-determined learning are based on students' owning and choosing their learning path and the process to learn, which "can also equip learners with the skills and capabilities that will help them better transition to the workforce" (Blaschke & Hase, 2015, p. 29). A shift toward personalization in education allows students to tailor to their individual needs in work and life.

Canning (2010) explored the process of implementing learning and teaching strategies that empowered learners to develop as heutagogic learners, which was observed in a foundational degree program in early childhood. The program aimed "to facilitate heutagogy [by] providing opportunities for self-directed learning and professional development, with students encouraged to take control over their own knowledge acquisition and the reflective process" (p. 60). Blended learning and teaching approaches were adopted, which included face-to-face seminars, online learning, work-based reflection, and tutor visits in both face-to-face and online settings. This created a flexible learning environment of both social and academic experiences in which learners personalized their approach to learning through reflective portfolios and utilized social networking forums to share personal and professional information.

At the outset of the program, the learners preferred a more traditional pedagogical structure in which teachers were depended upon as knowledge experts to inform what is to be learned, when, and how. The program created a learning environment that eased the learners towards heutagogy by "developing a community of open discussion, sharing experiences and supportive networks to facilitate the beginnings of self-directed study and motivated learners" (Canning, 2010, p. 62). This approach supported and increased the learners' confidence and allowed a sense of empowerment and self-efficacy to emerge. The work of Hase and Blaschke (2021b) recognized that learners need to have a certain level of motivation and self-efficacy to define their learning path. As one of the key principles, learner agency provides individuals with the competence and capability to bring together their past and present experiences to discover their own approaches to learning (Hase, 2014).

Accessible and Inclusive Learning and Heutagogy in Higher Online Education

Ensuring access to educational opportunities for everyone requires a transformation toward more accessible and inclusive learning approaches (World Economic Forum, 2020). In an Education 3.0 world (Harkins, 2008), technological advances such as social media, mobile devices, and software applications have increased access to information where learners can be more autonomous in their individual learning. The WEF (2020) suggested that accessibility to learn is increased through technology that include integrating multiple techniques such as "visual, audial, tactile, and kinesthetic methods" (p. 12) to create learning opportunities that suit the needs of all students. Heutagogy aligns with the WEF's accessible and inclusive learning practice based on the premise that it is considered a "net-centric theory", which is the connectivity of learners to technologies used in online learning (Anderson, 2010). Cochrane (2020) identified several advantages to applying heutagogy in online higher education that increases accessibility and inclusivity, such as empowering teachers to facilitate openness, develop assessment strategies that meet the needs of the individual, encourage active learning inside and outside of the classroom by establishing communities of practice, and provide accessibility and equitable access to technologies for both teacher and learner.

Agonács and Matos (2019) conducted a study to understand what empirical evidence existed to heutagogy in practice and found that "heutagogy and self-determined learning are predominantly linked in the studies to the online environment and digital technologies" (p. 234). Further to this, a qualitative study conducted by Tümen Akyıldız (2019) sought to discover the learner's perception on heutagogical implementation and its practicality. One of the research questions was based on "Technology integrated teaching" in which 55% of respondents recommended utilizing technology to be heutagogical learners" (p. 164). Blended learning environments also seemed to be a fit for heutagogical learning. Several studies proved that blended learning was one of the main success drivers for heutagogical learners because it provides multiple ways of knowing through different types of interactions that encourage the production of knowledge within formal and informal learning communities (Ashton & Newman, 2006; Canning, 2010; Singh, 2003).

Problem-based, Collaborative Learning and Reflection and Metacognition

The WEF (2020) recommended that learning needs to shift from processed-based learning, where teachers provide direct knowledge to students by demonstrating processes and formulas, to a problem-based approach, where students are assigned collaborative projects allowing opportunities to try multiple solutions to solve problems. Research conducted on problem-based approaches concluded that this approach to learning increased a student's ability to solve problems, provided a sense of ownership to what and how they learn, and developed strong learning communities (WEF, 2020). Heutagogy adheres to the practice of reflection and metacognition, which is a similar approach to problem-based learning. Reflection allows students to think about what they have learned and how they learned it (metacognition) by revisiting their potential solution and finding ways to improve or adjust outcomes (Blaschke, 2021; Hase & Blaschke, 2021a).

Reflection and metacognition are learning processes in which learners assess past and current experiences, knowledge, or behaviours which they use to inform future knowledge and actions (Barnett & O'Mahony, 2006). In other words, reflection and metacognition combine hindsight, insight, and foresight to work through problems. Blaschke (2021) accounts that "the reflection process also allows [learners] to practice more analytical and critical thinking and to engage in complex reasoning and problem-solving" (p. 1633). Essentially, reflection and metacognition can lead to higher levels of cognitive activity, strengthening a learner's ability to analyze and synthesize problems.

Lifelong and Student-Driven Learning

The WEF (2018) estimated that by 2022, an extra 101 days of learning will be needed to keep up with the changing work world. Ashton and Newman (2006) studied a group of academics in a university program preparing new teachers and found that "heutagogy provides an enriched teaching methodology for lifelong learning in universities in the 21st century" (p. 826) and Lock et al. (2021) recognized that the complexities of a changing world require people to be lifelong learners. This corroborates with the claims from heutagogy and Education 4.0, in which both emphasize the importance of developing lifelong learners to prepare them for an ever-changing work world (Hase & Blaschke, 2021; World Economic Forum, 2020).

Lifelong and student-driven learning in Education 4.0 and heutagogy depends on learner agency (Hase & Blaschke, 2021; World Economic Forum, 2020). Students have a voice and a choice on how they want to learn and assess when they need to learn. In a Delphi study on technology-enabled lifelong learning conducted by Lock, et al. (2021), they recognized that heutagogy's principles support and build lifelong learning skills (Table 3). The authors claimed: "By using a heutagogical approach to instructional design, students learn to make decisions with regard to their learning, become more autonomous learners, and develop the knowledge and skills to engage heutagogically beyond higher education as lifelong learners" (p. 1649). Examples of lifelong skills include creativity, flexibility, self-direction, and self-regulation to name a few, all of which are also skills and competencies needed to work and live in a dynamic and changing world (Blaschke, 2021).

Conclusion

Several of the articles explored in this paper raised the concern that all levels of education face many demands to address changes in employability and society in general. WEF's Education 4.0 framework was premised on the expectation that jobs will change and become more complex. Workers will need to quickly adapt to new and disruptive innovations that will affect how we live and work. According to Blaschke and Hase (2015), heutagogy provides a framework that develops self-determined lifelong learners with capabilities that will prepare them for the workforce of today and in the future. Its principles reflect the changing learning environment and recognizes the complex array of skills, competences, and capacities needed for today's workplace. Heutagogy addresses the call to action from the WEF (2020) who are urging educators, governments, and organizations to "connect, scale and mainstream these promising new models, standards and approaches, and ensure access to Education 4.0 for all" (p.6). This paper analyzed the literature and discovered findings to answer the research question: How does heutagogy in higher online education meet the needs of Education 4.0? A conceptual model was presented to illustrate that heutagogy's principles can address Education 4.0's learning approaches; however, heutagogy is only one practice that supports the needs of todays and future learners. Further studies are recommended about how heutagogy and other existing pedagogies, models, theories, and approaches can assist in transforming teaching and learning for the new era in theoretically sound practice.

References

Abdullah, Q. 'A., Humaidi, N., & Shahrom, M. (2020). Industry revolution 4.0: The readiness of graduates of higher education institutions for fulfilling job demands. *Romanian Journal of Information Technology and Automatic Control*, 15-26. http://doi.org/10.33436/v30i2y202002

Agonács, N., & Matos, J. F. (2019). Heutagogy and self-determined learning: A review of the published literature on the application and implementation of the theory. *Open Learning: The Journal of Open, Distance and E-Learning, 34*(3), 223-240. https://doi.org/10.1080/02680513.2018.1562329

Ally, M., & Wark, N. (2020). Sustainable development and education in the fourth industrial revolution (4ir). Commonwealth of Learning (COL). http://oasis.col.org/bitstream/handle/11599/3698/2020_Ally_Wark_SustainDev_in_4IR.pdf?sequence=1&isAllowed=y

Anderson, T. (2010). Theories for learning with emerging technologies. In G. Veletsianos (Ed.), *Emerging technologies in distance education* (pp. 35-50). Athabasca University Press. http://www.aupress.ca/books/120177/ebook/02_Veletsianos_2010-Emerging_Technologies_in_Distance_Education.pdf

Ashton, J., & Newman, L. (2006). An unfinished symphony: 21st century teacher education using knowledge creating heutagogies. *British Journal of Educational Technology*, *37*(6), 825–840. https://doi.org/10.1111/j.1467-8535.2006.00662.x

Barnett, B. G., & O'Mahony, G. R. (2006). Developing a culture of reflection: implications for school improvement. *Reflective Practice*, *7*(4), 499–523. https://doi.org/10.1080/14623940600987130

Blaschke, L. M. (2012). Heutagogy and lifelong learning: A review of heutagogical practice and self-determined learning. *The International Review of Research in Open and Distance Learning, 13*(1), 56-71. https://doi.org/10.19173/IRRODL.V13I1.1076

Blaschke, L. M. (2021). The dynamic mix of heutagogy and technology: Preparing learners for lifelong learning. *British Journal of Education Technology, 52*(4), 1629-1645. https://doi.org/10.1111/bjet.13105

Blaschke, L. M., & Hase, S. (2015). Heutagogy: A holistic framework for creating 21st century self-determined learners. In B. Gros, Kinshuk, & M. Maina. (Eds.), *The Future of Ubiquitous Learning: Lecture Notes in Educational Technology* (pp. 25-40). Springer. https://doi.org/10.1007/978-3-662-47724-3_2

Canning, N. (2010). Playing with heutagogy: Exploring strategies to empower mature learners in higher education. *Journal of Further and Higher Education*, *34*(1), 59–71. https://doi.org/10.1080/03098770903477102

Cochrane, T. (2020). Exploring #heutagogy. *Exploring Educational Technology (Weblog).* https://thomcochrane.wordpress.com/2020/10/14/exploring-heutagogy/

Davis, L., & Hase, S. (2001). The river of learning in the workplace. Research to reality: Putting VET research to work. *Proceedings of the Australian Vocational Education and Training Research Association (AVETRA) Conference*. https://files.eric.ed.gov/fulltext/ED456269.pdf

Ehlers, U.-D., & Kellermann, S. A. (2019). Future skills: The future of learning and higher education. *Results of the International Future Skills Delphi Survey*. https://www.learntechlib.org/p/208249/

Elayyan, S. (2021). The future of education according to the fourth industrial revolution. *Journal of Educational Technology & Online Learning, 4*(1), 23-30. http://doi.org/10.31681/jetol.737193

Fisk, P. (2017). Education 4.0 ... the future of learning will be dramatically different, in school and throughout life. https://www.peterfisk.com/2017/01/future-education-young-everyone-taught-together/

Gernstein, J. (2014). Moving from Education 1.0 through Education 2.0 towards Education 3.0. In L. M. Blaschke, C. Kenyon, & S. Hase (Eds.), *Experiences in self-determined learning* (pp. 83-96). Amazon.

Harkins, A. M. (2008). Leapfrog principles and practices: Core components of education 3.0 and 4.0. *Futures Research Quarterly, 24*(1), 19-31.

Hase, S. (2014). An introduction to self-determined learning (Heutagogy). In L. Blaschke, C. Kenyon, & S. Hase, *Experiences in self-determined learning* (pp. 15-30). https://www.researchgate.net/publication/268684257_Experiences_in_self-determined_learning/stats#fullTextFileContent

Hase, S., & Blaschke, L. (2021a). So, you want to do heutagogy: Principles and practice. In S. Hase, & L. M. Blaschke, *Unleashing the power of learner agency* (pp. 13-33). Edtechbooks.org. https://edtechbooks.org/up/pp

Hase, S., & Blaschke, L. (2021b). The pedagogy of learner agency. In S. Hase, & L. M. Blaschke, *Unleashing the power of learner agency* (pp. 4-12). Edtechbooks.org. https://edtechbooks.org/up/pp

Hase, S., & Davis, L. (1999, August 6-8). From competence to capability: The implications for human resource development and management. *Proceedings of Millennial Challenges in Management, Education, Cybertechnology, and Leadership: Association of International Management, 17th Annual Conference. San Diego, CA, USA.*

Hase, S., & Kenyon, C. (2000). From andragogy to heutagogy. *In Utilbase Articles*. https://webarchive.nla.gov.au/awa/20010220130000/http://ultibase.rmit.edu.au/Articles/dec00/hase2.htm

Hussin, A. A. (2018). Education 4.0 made simple: Ideas for teaching. *International Journal of Education & Literacy Studies, 6*(3), 92-92. https://files.eric.ed.gov/fulltext/EJ1190812.pdf

Institute for the Future. (2013, November 9). *From Educational Institutions to Learning Flows.* https://www.iftf.org/uploads/media/SR-1580-IFTF_Future_of_Learning_01.pdf

Ishak, R., & Mansor, M. (2020). The relationship between knowledge management and organizational learning with academic staff readiness for education 4.0. *Eurasian Journal of Education Research, 85*, 169-184.

JISC. (2019). *Preparing for Education 4.0.* https://www.timeshighereducation.com/hub/jisc/p/preparing-education-40

Koul, S., & Nayar, B. (2021). The holistic learning educational ecosystem: A classroom 4.0 perspective. *Higher Education Quarterly, 75*, 98-112. https://doi.org/10.1111/hequ.12271

Lock, J., Lakhal, S., Cleveland-Innes, M., Arancibia, P., Dell, D., & De Silva, N. (2021). Creating technology-enabled lifelong learning: A heutagogical approach. *British Journal of Educational Technology, 52*(4), 1646-1662. https://doi.org/10.1111/bjet.13122

McAuliffe, M., Hargreaves, D., Winter, A., & Chadwick, G. (2009). Does pedagogy still rule? *Australian Journal of Engineering, 15*, 13-18. https://doi.org/10.1080/22054952.2009.11464018

Nagarajan, R., & Prabhu, R. (2015). Competence and capability: A new look. *The International Journal of Management, 6*(6), 7-11.

Redecker, C., & Punie, Y. (2017). *European framework for the digital competence of educators: DigCompEdu.* Luxembourg: Publications Office of the European Commission. https://data.europa.eu/doi/10.2760/159770

Sala, A., Punie, Y., Garkov, V., & Cabrera, M. (2020). *LifeComp: The european framework for personal, social and learning to learn key competence, EUR 30246 EN.* Publications Office of the European Union. https://doi.org/10.2760/302967

Salmon, G. (2017). *Higher Education 1.0 to Education 3.0 and Beyond.* https://www.gillysalmon.com/blog/higher-education-3-0-and-beyond

Salmon, G. (2019). May the fourth be with you: Creating education 4.0. *Journal of Learning for Development, 6*(2), 95-115. https://doi.org/10.56059/jl4d.v6i2.352

Schwab, K. (2016). *The fourth industrial revolution: What it means and how to respond*. World Economic Forum. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond

Shahroom, A. A., & Hussin, N. (2018). Industrial revolution 4.0 and education. *International Journal of Academic Research in Business and Social Sciences, 8*(9), 314-319. https://doi.org/10.6007/IJARBSS/v8-i9/4593

Singh, H. (2003). Building effective blended learning programmes. *Issues of Educational Technology*, *43*(6), 51–54.

Tümen Akyıldız, S. (2019). Do 21st century teachers know about heutagogy or do they still adhere to traditional pedagogy and andragogy? *International Journal of Progressive Education*, *15*(6), 151–169. https://doi.org/10.29329/ijpe.2019.215.10

World Economic Forum. (2018). *The future of jobs report 2018*. https://www3.weforum.org/docs/WEF_Future_of_Jobs_2018.pdf

World Economic Forum. (2020). Schools of the future: Defining new models of education for the fourth industrial revolution. *World Economic Forum*, 1–33.

Xing, B., & Marwala, T. (2017). Implications of the fourth industrial age for higher education. *The Thinker (73 Third Quarter)*, 10-15. Available at SSRN: https://ssrn.com/abstract=3225331

Zahidi, S. (Saadia Zahidi). (2019, December 16). *How are the forum partners advancing prosperous, inclusive, equitable economies and societies?* [Video]. YouTube. https://www.youtube.com/watch?v=wmRY63R650U&t=1s

Author

Jeanne Kim is a student in the Doctor of Education in Distance Education Program, Faculty of Humanities and Social Sciences, Athabasca University, Canada. Her current research focuses on 21st century skills and their impacts on how we teach, learn, and work. Email: mkim@athabasca.edu. ORCID: https:// orcid.org/0000-0002-5434-0399

CJLT RCAT
Canadian Journal of Learning and Technology
La Revue canadienne de l'apprentissage et de la technologie

Volume 48 (4) Special Issue 2022

Dynamic Evolution Analysis of Social Network in cMOOC based on RSiena Mode

Analyze dynamique de l'évolution du réseau social dans le cMOOC basé sur le mode RSiena

***Yaqian Xu**, Beijing Normal University, China*

***Junlei Du**, Beijing Normal University, China*

Abstract

The network is a key concept which has been highly valued in connectivism. Research about the static characteristics of social networks in connectivist learning has been carried out in recent years, however, little knowledge exists regarding the principles of network evolution from a dynamic perspective. This article chose the first connectivist massive open and online course (cMOOC) in China, "Internet plus Education: Dialogue between Theory and Practice" as the research object, using the dynamic analysis method of social networks which is based on stochastic actor-oriented models, to reveal the influence of the individual attributes and network structural attributes on the dynamic evolution of social networks in a cMOOC. We found that: 1) the learners with the same sex, the same social identity, and the same type of behaviour tendency found it much easier to interact with each other; 2) there is a heterogeneous phenomenon with course identity, meaning that compared to communicating with other learners, learners are more inclined to reply to a facilitator; and 3) the reciprocity and transitivity have significant effects on social network evolution. This study is valuable for understanding the network evolution and has implications for the improvement of cMOOC design, in turn improving the online learning experience for cMOOC learners.

Keywords: cMOOC; Social network; SIENA; Evolution; Interaction; Connectivism

Résumé

Le réseau est un concept essentiel qui a été fortement valorisé dans le connectivisme. Quelques recherches ont été menées ces dernières années sur les caractéristiques statiques des réseaux sociaux dans l'apprentissage connectiviste. Cependant, il existe peu de connaissances sur les principes d'évolution des réseaux d'un point de vue dynamique. Cet article a choisi le premier cours connectiviste de formation en ligne ouverte à tous (cMOOC) en Chine, "Internet plus Éducation : Dialogue entre la théorie et la pratique" comme objet de recherche, en utilisant la méthode d'analyse dynamique des réseaux sociaux qui est basée sur des modèles stochastiques orientés vers les acteurs, pour révéler l'influence des attributs individuels et celles des attributs structurels du réseau sur l'évolution dynamique des réseaux sociaux dans un cMOOC. Nous avons constaté que : (1) les apprenants ayant le même sexe, la même identité sociale et le même type de tendance comportementale trouvent qu'il est beaucoup plus facile d'interagir les uns avec les autres ; (2) il existe un phénomène hétérogène avec l'identité du cours, ce qui signifie que par rapport à la communication avec d'autres apprenants, les apprenants sont plus susceptibles de répondre à un facilitateur ; (3) la réciprocité et la transitivité ont des effets significatifs sur l'évolution des réseaux sociaux. Cette étude est utile pour comprendre l'évolution du réseau et a des implications pour l'amélioration de la conception du cMOOC, améliorant à son tour l'expérience d'apprentissage en ligne pour les apprenants du cMOOC.

Mots clés : cMOOC ; réseau social ; Siena ; évolution ; interaction ; connectivisme

Introduction

Connectivist learning reveals a new idea to solve complex problems and create knowledge by continuously connecting high-quality nodes, especially adapting to the new characteristics of the networked knowledge in the era of "Internet +" (Downes, 2012). When the needs and problems are constantly changing, and the knowledge becomes dynamic, uncertain, and unpredictable, it’s more important to build good networks that can adapt to change than to memorize and store knowledge (Downes, 2017). The cMOOC is a typical practice of connectivism. Different from traditional online courses represented by the eXtended massive open online courses (xMOOC), there are new learning rules existing in connectivist learning. Understanding the new rules is crucial to the design of cMOOCs and improving the learner’s learning experience. According to connectivism, learning is a process of connection building and network development (Siemens, 2005). The characteristics and interaction mechanism of the three networks - internal cognitive neural network, concept network, and social network - are the key issue in revealing learning rules (Wang & Chen, 2017). Complex social networks are generated by participants through continuous interaction in distributed learning space, and the network structure expands and evolves with the deepening of interaction. The exploration of the dynamic evolutionary mechanism of networks can provide fundamental support for analyzing the interactive tendency of connectivist learners and assist facilitators to improve design and service. In October 2018, Professor Chen Li and her team from Beijing Normal University designed the first cMOOC in China, “Internet plus Education: Dialogue between Theory and Practice”. By August 2021, the cMOOC had been delivered six times and the learning data received from these six offerings were used for this study which revealed the dynamic evolution principles of social networks. Using data from the platform of cMOOC2.0, and with the help of the stochastic actor-oriented model, this study aimed to measure and explain how the social network in cMOOC forms and evolves.

Literature Review

Social network analysis (SNA) is used to quantify the structure of social networks at various levels (role, two-dimensional, three-dimensional, etc.), and to better explain the basic problems in connectivist learning from the perspective of the network. How are connections formed and maintained? How do roles and relationships affect learning?

Benefiting from the development of big data and complex network analysis methods, SNA has been applied to MOOC studies and much research has been carried out to explore interaction patterns in forums, blogs, and microblogs. Among them, Chinese researchers mostly focus on summarizing the characteristics and analyzing the static properties of social networks. For example, reciprocity was used to measure the number of bilateral relationships and judge one-way interaction with the help of average distance and network diameter (Song et al., 2014). Block model analysis was carried out to reveal the internal sub-structure of the network, reflecting the closeness and breadth of interaction among members (Guo et al., 2020). Additionally, interaction tendency among bloggers (Wang et al., 2012) and the ecological structure of the online community; the relationship between subgroups was visualized and analyzed to find special roles like broker, sender, and receiver (Liu et al., 2018). Lastly, some studies used in-degree, out-degree, betweenness centrality, and other indexes to build an assessment model of individual network status and identify the differences in academic performance of individuals with different importance (Xu & Du, 2021; Liang, 2018). Very few researchers have analyzed network evolution from a dynamic perspective, such as counting density, edges, and nodes in different periods to reflect the evolution of social networks (Wu et al., 2016). In the West, this research direction has received growing attention over recent years. Yang et al. (2013) measured the different periods of the network to explore how the learners interact with the existing community; Kellogg et al. (2014) studied peer-assisted learning in MOOC forums by SNA and found that MOOCs can more effectively foster the networks and promote the occurrence of peer-assisted learning. These types of studies revealed the evolution phenomenon of the social network by generating static snapshots of a network at different points but did not connect the observed behaviours to the underlying effects of network structure and the characteristics of learners (Zhang et al., 2016).

Research on connectivist learning in China and abroad has grown since 2010. More current research is attending to learning environments and resources, theory analysis, interaction patterns, characteristics of learners, and activity design. In recent years, the static characteristics and relationships of networks have received growing research attention, such as the structure of the whole social network (Wang et al., 2018), the correlation between individual network status as well as other variables like academic performance and concept generation (Duan et al., 2019; Xu & Chen, 2019). Despite the extensive literature examining SNA, one issue that remains less explored is the dynamic evolution mechanism of the network, which may lead to the interpretation of how connectivist learning happened. Therefore, it is prudent to use the simulation investigation for empirical network analysis (SIENA) to explore the characteristics of structural changes of networks in cMOOC to better understand the social complexity of connectivist learning. The laws behind its evolution can help us understand how interaction occurs in connectionism learning and provide references for optimizing learning support services and recommendation mechanisms in cMOOC, to improve the way-finding efficiency and learning experience of cMOOC learners.

Hypothesis

The establishment and deletion of connections in a network is the fundamental cause of network topology change. Earlier studies evaluated found that the individual attributes and network structure attributes had an influence on the evolution of relationships in social networks (Albert & Barabasi, 2001). This study also discusses the effects of these two dimensions on the evolution of social networks in cMOOCs.

Effects of Individual Attributes (Homophily)

The homophile was first proposed by Lazarsfeld and Merton in 1954, which suggests people are more inclined to establish relationships with individuals who are like themselves or have the same attributes (McPherson et al., 2001). It is reasonable to assume that homophile is important to the development of learners' interaction. The spread of knowledge and exchange of ideas is much more likely to occur between similar groups than among other groups (Rogers, 1995, p. 18). In previous relationship analysis of online communities, demographic attributes (like sex and age) and experience similarity (like illness, etc.) were often used as factors to determine homophiles (Wu et al., 2017). This study selected five individual attribute factors: 1) sex ("male" or "female"); 2) field of interest ("curriculum and resource design," "technology and product development," "law and method research," "service and marketing," or "policy and institutional innovation"); 3) social identity ("education manager," "industry elite," "teacher," or "student"); 4) course identity ("facilitator" or "learner"); and 5) behavioural tendency ("like," "blogging," "follow," or "comment").

The reasons for selecting the above attributes are as follows: 1) sex is treated as a significant factor influencing the establishment of relations in online communities; 2) field of interest and social identity can reflect the similarity of participants' experiences; 3) course identity can help us understand and verify the role of facilitators in the construction of connectivist social network; and 4) behavioural tendency is used to distinguish the influence of individual interactive habits on connection establishment. Therefore, the following hypotheses are proposed in this study:

- **H1a**: With the development of connectivist learning, participants of the same sex are more likely to interact with each other.
- **H1b**: With the development of connectivist learning, participants in the same field of interest are more likely to interact with each other.
- **H1c**: With the development of connectivist learning, individuals with the same social identity are more likely to interact with each other.
- **H1d**: With the development of connectivist learning, the frequency of learners' interaction with other learners is much higher than that with facilitators.
- **H1e**: With the development of connectivist learning, individuals with the same behavioural tendency are more likely to interact with each other.

Effects of Network Structure Attributes

Reciprocity

Reciprocity is an important evaluation index of the interaction in networks, which is a two-dimensional statistical process calculated by a union vector. Reciprocity refers to the back-and-forth in communication (if A replies to B, then B replies to A). Former studies have shown that in the process of interaction, learners not only express their own views but also establish communication relationships with others by replying to the content posted by others. Reciprocal interaction is conducive to promoting cognitive socialization (Arvaja et al., 2003). Therefore, the following additional hypothesis is proposed in this study:

- **H2**: In connectivist learning, there is an increasing tendency towards reciprocity in social networks over time.

Transitivity

Transitivity, that is, if A is related to B, and B is related to C, then A is related to C, makes sense for networked learning. In the virtual environment, it is the transmission of trust and opportunity in the learners' community. cMOOC learners can access other learners' personal home pages by course platform to find out its focus on the list. In other words, due to the mediation of B, there is more opportunity for A and C to connect with each other. Kossinets and Watts (2006) conducted an experimental study and found that the more common friends two individuals have, the likelihood of establishing a relationship will increase significantly. At the same time, different learning groups can provide learners with different resources, and learners can obtain the resources they need by communicating with different peers. In other words, the more obvious the transitivity in the network is, the greater the supporting effect for learning will be. Moreover, transitivity can also increase network closure. In a closed group, trust can be established among members to form a mutually supportive environment. Therefore, the following hypothesis is proposed in this study:

- **H3**: In connectivist learning, there is an increasing tendency towards transitivity in social networks over time.

Preferential Attachment (Matthew Effect)

The Matthew effect represents a positive feedback loop generating a power-law distribution in a network (Zhang et al., 2016). In other words, the rich get richer. In education, it can be understood that individuals in the center of the network or with greater influence will receive more attention and interaction, which reflects the polarization phenomenon in the network. Once these important individuals quit, it will cause great damage to the whole social network, and even lead to the collapse of the network structure and affect the continuation of the whole interaction in learning. On one hand, there will be central participants in a highly centralized network and it's conducive to the efficient transmission of information. On the other hand, the high imbalance of power in such networks isn't beneficial to collective intelligence communication, and the network structure is fragile. Zhang et al. (2016) discovered that there is a tendency towards preferential attachment in MOOC networks. Therefore, the following hypotheses are proposed in this study:

- **H4**: In connectivist learning, there is a tendency of Matthew effect in social networks over time.

Methods

Context and Data Collection

The cMOOC2.0 offering of "Internet plus Education: Dialogue between Theory and Practice", was selected as the research context in this study. There were 1,550 Chinese learners registered and it ran for 12 weeks. The course was built on five themes: 1) the philosophy of "Internet plus education"; 2) the fusion of online and offline learning spaces; 3) co-construction and sharing of social education resources; 4) consumption-driven education supply-side reform; and 5) accurate and efficient education management model. During the course, learners can establish social network relationships through various behaviours including liking, commenting, and discussing. The data collected in this study includes personal attribute data (sex, the field of interest, social identity, learning identity), individual behaviour frequency data (like, blogging, follow, comment), and network construction data (interactive data). In the end, 22,468 pieces of behavioural data were collected including 7,473 pieces of "like" data, 4,083 pieces of "follow" data, 9,654 pieces of "comment" data (including posting and reply), and 1,258 pieces of "blogging" data.

In this study, the social network of cMOOC2.0 was divided according to the running time of each theme. The basic attributes of the network in the eight stages are shown in Table 1. The Jaccard coefficients of the two adjacent stages were calculated, which were 0.341, 0.833, 0.869, 0.975, 0.935, 0.934 and 0.963 (all greater than 0.3), indicating that the network was stable and smooth between the two continuous periods. Therefore, the eight periods were properly divided and suitable for SIENA analysis.

Table 1

Basic Attributes of Social Networks in Eight Stages

	Guiding Week	Theme 1	Theme 2	Theme 3	Mid-term	Theme 4	Theme 5	Ending Week
Run Time	03.08 -03.19	03.20 -04.02	04.03 -04.16	04.17 -04.30	05.01 -05.07	05.08- 05.21	05.22 -06.04	06.05 -06.15
Nodes	688	1154	809	804	251	680	734	477
Edges	2105	5984	2682	2990	496	2316	3216	1421
Density	0.006	0.017	0.020	0.023	0.024	0.025	0.027	0.028
Average Degree	3.000	8.787	10.554	12.148	12.465	13.326	14.266	14.816

Methods

Based on the stochastic actor-oriented model, this study chooses the R package “RSiena” as the tool for dynamic analysis of social networks in cMOOC. The advantage of this model is that it can analyze the dynamic evolution of the network based on the Markov chain. According to the stochastic actor-oriented model, the formation and evolution of the network are determined by the actions of nodes in the network, and each node decides to establish, maintain, or cancel connections by themselves, which ultimately affects the change of the entire network. The model takes the change of the network as the dependent variable, and the node attributes, network structure, and other random variables as the factors that change the connection of the node (Snijders et al., 2010).

The objective function is used to calculate the overall structural effect preferred by nodes among all possible network structures. Objective function mainly depends on structural effect and covariate effect. The structural effect measured in this study includes “reciprocity”, “transitive triplets”, and “out-degree related popularity (SQRT)”. Reciprocity calculates the probability of B's reply to A in the case of A having replied to B. Transitive triplets are represented by the number of connections between individuals and their friends' friends, which can reflect the tendency of transitivity in the networks. The SQRT is used to measure the attractiveness of an actor, that is, an individual who has received many responses is likely to be responded to by others. The covariate effect is based on the internal factors to measure the dynamic characteristics of the network, and this study chose the “same V” effect to measure the tendency of the node’s connection to others with equal attribute values. This study focused on five attributes (sex, areas of interest, social identity, course identity, and behavioural tendency) to reflect the effects of homogeneity on the evolution of social networks. If the estimated value of the same V effect of an attribute is positive, then two nodes with the same value of this attribute are more likely to form a connecting edge. In the SIENA model, the conditional method of moments estimation was used for data analysis, and the total number of changes in the observed network was used to represent the conditional variables. If the aggregation of the model is too low (i.e., the value of t-ratios in the model is higher than 0.25), the obtained results will be taken as the starting value and analyzed again until the aggregation degree reaches the standard (Ripley et al., 2015).

Results

Effects of Individual Attributes on Evolution of Social Networks in a cMOOC

This study proposed hypotheses on the influence of sex, field of interest, social identity, course identity, and behavioural tendency on the evolution of the social network in a cMOOC. Table 2 shows the estimated results of the stochastic actor-oriented model. In terms of the t-ratios value of each attribute, the model fitting precision of "(1) → (2)" (from guiding week to theme 1) and "(5) → (6)" (from mid-term week to theme 4) was poor (t-ratios> 0.1). The main reason is that there are no specific themes and learning tasks during the guiding week and the mid-term summary week. Consequently, the results cannot reflect the actual learning situation of cMOOC and cannot interpret the evolution law of social networks in cMOOC. T-ratios in other periods were mostly less than 0.1, so the significance of effect values in other periods should be mainly considered in the analysis. The method to judge whether the effect is significant or not is to divide the value outside parentheses by the value inside parentheses. If it is greater than 2, the effect is proved to be significant at the level of 0.05.

Table 2

Results of Covariate Effect by Rsiena

		(1)→(2)	(2)→(3)	(3)→(4)	(4)→(5)	(5)→(6)	(6)→(7)	(7)→(8)
Sex		-0.0629	0.4071**	0.3339**	0.6630	0.1510	0.1507**	0.0055
		(0.0348)	(0.0688)	(0.0474)	(0.5085)	(0.2121)	(0.0741)	(0.0626)
	t-ratios	**-0.1851**	0.0434	-0.0370	-0.0890	**-0.3613**	-0.0556	**-0.1581**
Field of interest		-0.1890**	-0.0075	0.4021**	0.0308	0.0267	0.0042	-0.2132**
		(0.0483)	(0.0539)	(0.0486)	(0.1829)	(0.3190)	(0.0597)	(0.1050)
	t-ratios	**-0.3993**	-0.0325	**-0.2427**	-0.0864	**-0.4309**	**-0.2494**	-0.0062
Social identity		0.0621	0.4497**	0.5640**	0.2563	1.0923**	0.3905**	0.2898**
		(0.0331)	(0.0592)	(0.0441)	(0.1364)	(0.1184)	(0.0791)	(0.0960)
	t-ratios	0.0798	0.0065	0.0003	0.0507	**0.1840**	0.0705	0.0105
Course identity		-0.5952**	-0.5760**	-0.1464	-0.9789**	-0.8097	-0.6957**	-0.8660**
		(0.1472)	(0.0529)	(0.0750)	(0.2665)	(0.5233)	(0.1119)	(0.1484)
	t-ratios	**0.5839**	0.0389	**-0.2724**	**-0.2363**	**-0.5483**	**-0.1442**	0.0425
Behavioural tendency		0.1286**	0.0665	0.5176**	0.4353	0.4032**	0.3104**	0.2646**
		(0.0370)	(0.0388)	(0.0756)	(0.4836)	(0.1227)	(0.0654)	(0.1068)
	t-ratios	**-0.1648**	-0.0139	0.0573	-0.0690	**-0.2977**	0.0006	**-0.1505**

** significant at $p<0.05$; the values of t-ratios in bold mean the model fitting precision of it was poor.

Impact of "sex" on the Evolution of Social Networks in cMOOC

As shown in Table 2, the absolute value of t-ratios of sex was less than 0.1 during the main theme-learning period. In the evolution stages of "(2) → (3)", "(3) → (4)" and "(6) → (7)", sex had a significant effect on network changes and the estimated value of parameters was positive, up to 0.6630, indicating that it is easier for learners of the same sex to establish connections, which **confirms hypothesis H1a**. Earlier studies have shown that people of the same sex have higher similarities in thinking mode, perspective, and mentality, and are more likely to understand each other and establish a sense of trust in the process of communication on the same topic (Durant et al, 2012; Wu et al., 2017). cMOOC learning obviously follows this rule as well.

Impact of “Field of Interest” on the Evolution of Social Networks in cMOOC

According to the estimation results of the t-ratios, only the three evolution stages of "(2) → (3)", "(4) → (5)", and "(7) → (8)" have a good model fitting performance. Unfortunately, the field of interest only has a significant influence on the network evolution of "(7) → (8)" and the parameter estimation value is negative, meaning learners with different fields of interest are more likely to establish connections. It’s obvious that the influence of fields of interest on network changes is unstable and insignificant in most cases, i.e., **H1b is rejected**. cMOOC learners will contact vast amounts of generative content which is not in accordance with the areas of interest, and most content is interdisciplinary which supports discussion from multiple perspectives. Thus, learners’ interaction mainly depends on whether the idea can resonate or provoke thought, namely the learner may publish or reply to content in different areas.

Impact of “Social Identity” on the Evolution of Social Networks in cMOOC

As shown in Table 2, except for "(5) → (6)", the absolute value of t-ratios of social identity was less than 0.1, therefore, the model results are reliable. Social identity has a significant effect on the evolution of adjacent networks, and the parameter estimation value was positive, indicating that participants with the same social identity were more likely to establish connections. **H1c is accepted**. Individuals with similar social identities tend to have similar discourse systems, similar experiences, similar knowledge backgrounds and abilities, so there are more common topics that they are familiar with; and the problems they faced and the perspective they followed are also similar, so they are more likely to connect with each other. Therefore, learners with the same social identity are more likely to interact with each other.

Impact of “Course Identity” on the Evolution of Social Networks in cMOOC

According to the estimation results of t-ratios, only "(2) → (3)" and "(7) → (8)" models have better fitting effects, where the influence of course identity is significant at the level of 0.05, and the estimated value of parameters is negative, indicating that individuals with different course identities are likely to establish connections. That is, it is easier to establish a connection between facilitators and learners in cMOOC, so **H1d is rejected**. Connectivism emphasizes the interaction between learners, and that learners promote the generation of content, and the aggregation and contribution of learners' experience is the main way to solve problems (Chen et al., 2019). This result shows that in this cMOOC, facilitators are the important roles for most learners, and most learners are still willing to actively establish and maintain contact with facilitators. However, this result still needs to be verified in other cMOOCs.

Impact of "Behavioural Orientation" on the Evolution of Social Networks in cMOOC

As shown in Table 2, the t-ratios were less than 0.1 in "(3) → (4)" and "(6) → (7)" phases, and behavioural tendency had a significant effect on network changes with positive estimated parameter values. It means that learners with the same behavioural tendency were more likely to establish connections, so **H1e is accepted in some cases**. There are a variety of interactive ways provided in cMOOC, including posts, thumbs up, comments, concerns, etc. In general, the learner's behaviour reflects their habitual and preferred modes of interaction. Meanwhile, learners will pay particular attention to their preferred interactions. In other words, learners with the same interaction behaviour may have more opportunities to connect because they communicate based on their behaviour type.

Effects of Network Structure Attributes on Evolution of Social Networks in a cMOOC

This study focuses on the effects of reciprocity, transitivity, and preferential attachment on the evolution of social networks in cMOOC. Table 3 shows the estimated results by the RSiena model.

Table 3

Results of Network Structure Attributes' Effects by RSiena

	(1)→(2)	(2)→(3)	(3)→(4)	(4)→(5)	(5)→(6)	(6)→(7)	(7)→(8)
Reciprocity	2.2091**	1.5421**	1.9210**	3.5725**	4.9948**	1.7076**	1.4944**
	(0.0815)	(0.1602)	(0.1053)	(0.4516)	(0.6085)	(0.1532)	(0.2887)
t-ratios	0.0358	0.0445	**0.1248**	0.0021	-0.0845	0.0697	-0.0596
Transitivity	0.1049**	0.0739**	0.1072**	0.1100	0.5165**	0.1376**	0.1172**
	(0.0068)	(0.0030)	(0.0055)	(0.0901)	(0.0556)	(0.0083)	(0.0112)
t-ratios	0.0347	0.0414	0.0915	**-0.2297**	-0.0524	0.0679	-0.0907
Preferential attachment	0.1608	0.7270**	0.2665	0.6813	-1.3415	-0.0647	0.1158
	(0.1440)	(0.1069)	(0.1944)	(2.7710)	(1.2880)	(0.1553)	(0.1664)
t-ratios	0.0989	-0.0760	**-0.1455**	**-0.2263**	**-0.1297**	**-0.1494**	**-0.1226**

** significant at p<0.05; The values of t-ratios in bold mean the model fitting precision of it was poor.

Impact of "Reciprocity" on the Evolution of Social Networks in cMOOC

As shown in Table 3, the absolute value of t-ratios in other periods except "(3) → (4)" was less than 0.1. Reciprocity has a significant effect on network changes at the level of 0.05 and the estimated parameter values are positive, which range from 1.4944 to 4.9948 in different periods. It indicates that the reciprocity of social networks in cMOOC increases over time. **H2 is accepted**. During cMOOC learning, there are vast amounts of generative, fragmented, and distributed contents in an open network environment, and the learners need to independently filter unprofitable information and build valuable connections. It should be noted that the comments or replies from others can be presented to learners by the system automatically, which shortens the way-finding path between senders and receivers. Therefore, compared to others, it’s easier to establish a two-way interaction.

Impact of “Transitivity” on the Evolution of Social Networks in a cMOOC

As shown in Table 3, for single t-ratios, very few absolute values are greater than 0.1, indicating good model fitting performance. The effect of transitivity on network changes is significant at the level of 0.05. The estimated values of parameters are positive, meaning that individuals in cMOOCs were more inclined to establish contacts with friends’ friends. As the social network changes over time, the transitivity (network closure) continues to increase and the network cohesion is enhanced, which **confirms hypothesis H3**. This is because in community activities, individuals usually have a higher sense of trust towards friends’ friends, and the behaviours or interactions of the learners they focus on are more likely to lead to their attention. Through the intermediary role of friends, the opportunity to communicate with their friends also greatly increased, thus promoting the interactions between individuals and their friends’ friends.

Impact of “Preferential Attachment” on the Evolution of Social Networks in cMOOC

According to the model fitting results, the fitting effect of the network evolution model was not good from theme 2 forward because only the absolute value of t-ratios in "(2) → (3)" was less than 0.1. The effect of preferential attachment in this period is significant at the level of 0.05, and the estimated value of parameters is positive, indicating that there is a Matthew effect in the social network at the early stage of cMOOC learning, that is, individuals at the centre of the network with greater influence will gain more attention and interaction in later learning. This is because when new learners enter the learning community, active learners are more likely to attract their attention in the unfamiliar learning environment. But with the development of learning, learners gradually adapted to the complex information environment, the problem-driven and theme-based discussion will become the main tendency of interaction. From the whole stage of the course, the tendency of a preferential attachment effect is not stable, and the Matthew effect is not obvious in the evolution of social networks (although the model fitting effect is not good, the parameter estimates are sometimes positive and sometimes negative), so the hypothesis **H4 is rejected**. This effect still needs to be verified in more cMOOC contexts.

Discussion and Conclusions

Supported by the first cMOOC in China, using the stochastic actor-oriented model, this study analyzes the factors influencing the dynamic evolution of social networks from two dimensions of individual attributes and network structural attributes and reveals the evolutional mechanism of social network structure in a cMOOC. The results will provide support for designing more effective activities, recommendations, and pathfinding mechanisms.

This study found that there is homogeneity during the evolution of social networks in cMOOC. Connectivist learners are more inclined to communicate and establish connections with other learners of the same sex, social identity, and behavioural tendency. This finding has also been confirmed in former studies on the evolution of online community relations in other fields. Social relationships are easier to establish and maintain between individuals with similar identical attributes (Wang et al., 2008; Durant et al., 2012). Therefore, to promote the formation of a closer social network structure and the establishment of connections between learners, the partner recommendation mechanism can be designed according to the similarity of sex, social identity, and behavioural tendency, so that the promoting effect of curriculum design on wayfinding can be brought into play.

However, there is a heterogeneous phenomenon during the evolution of social networks in cMOOC in terms of course identity. Compared to communicating with other learners, learners are more inclined to reply to the content posted by the facilitator. Kellogg et al. (2014) found that students play an important role in promoting forum interaction. The connectivism theory also emphasizes that learners are the main contributors and creators of course content, and connectivist learning relies on learners' active participation (Anderson, 2009). This study takes the cMOOC as the research context, due to the influence of traditional education styles, the idea of teacher-centred, and the teacher as the authority still affects most Chinese learners. For most connectivist beginners, teachers are important nodes in the network and the information amplified and spread by teachers is more valuable and influential (Zhang et al., 2016; Xu, 2020). In this type of network, the information transmission speed of the facilitators to learners is much faster than that between learners, however, the number of learners in cMOOCs tends to be one hundred times as many as the number of facilitators. Therefore, this heterogeneous phenomenon is not conducive to the rapid dissemination of information in the network. When designing cMOOCs, facilitators, as an important learning partner, need to help beginners make diversely wayfinding through demonstration (Dron, 2013) and connectivism emphasized learning support distributed in the community (Downes, 2017) can establish incentive mechanism to promote peer support and role models, which is key to dealing with this challenge in mass group learning.

In terms of network structural attributes, we also find that reciprocity and transitivity have significant effects on the evolution of social networks in cMOOCs. This finding is reasonable and consistent with previous research. For example, Zhang et al. (2016) found that MOOC learners tend to reply to reciprocal partners and establish connections with others in a transmission way. Waite et al. (2013) proved the reciprocal relationship of learners' participation in MOOCs by qualitative research. This study demonstrated that there are some significant effects of reciprocity and transitivity on social networks in cMOOCs as same as xMOOCs. Therefore, when designing cMOOCs, the reciprocity and transitivity can be used to optimize the functional modules of the platform, whereby the original content list arranged in chronological order can be changed (Buder et al., 2015) to highlight high-quality and learner-related content to guide the attention distribution of learners. As an alternative, the reciprocity and transitivity can be used to optimize the partner and content recommendation mechanism, such as pushing the posts or comments from friends and guiding learners to actively comment on the content posted by individuals with high response rates.

In conclusion, this study is a beneficial attempt to reveal the dynamic evolution laws of social networks in connectivist learning based on empirical evidence, which to some extent supports the improvement and optimization of cMOOC design in learning support services, environment, recommendation mechanism, and other aspects. However, the model fitting performance of two attributes (course identity and preferential attachment) is not sufficient in this study, and this study is rooted in a Chinese educational practice context; that is, the results and discussions still need to be verified in more cMOOC contexts with various cultural backgrounds. Meanwhile, further studies should also be explored to reveal the impact of intervention strategies on the evolution of social networks.

Acknowledgements

This research is supported by the project "Research on the management of education reform and innovation in the era of 'Internet plus'" funded by The National Natural Science Foundation of China (NSFC), [Grant No. 71834002].

References

Albert, R., & Barabási, A.-L. (2001). Statistical mechanics of complex networks. *Reviews of Modern Physics*, *74*(1), 47-97. https://doi.org/10.1103/RevModPhys.74.47

Anderson, T. (2009). The dance of technology and pedagogy in self-paced distance education. http://hdl.handle.net/2149/2210

Arvaja, M., Rasku-Puttonen, H., Häkkinen, P., & Eteläpelto, A. (2003). Constructing Knowledge through a Role-Play in a Web-Based Learning Environment. *Journal of Educational Computing Research*, *28*(4), 319–341. https://www.learntechlib.org/p/69173

Buder, J., Schwind, C., Rudat, A., & Bodemer, D. (2015). Selective reading of large online forum discussions: The impact of rating visualizations on navigation and learning. *Computers in Human Behavior*, *44*, 191–201. http://doi.org/10.1016/j.chb.2014.11.043

Chen, L., Lu, H., & Zheng, Q.H. (2019). Conceptualizing knowledge in "Internet + education": the nature of knowledge and knowledge evolution. *Distance Education in China*, (07), 10-18+92. https://doi.org/10.13541/j.cnki.chinade.2019.07.003.

Downes, S. (2012). Connectivism and Connective Knowledge: Essays on meaning and learning networks. National Research Council Canada. https://www.oerknowledgecloud.org/record705

Downes, S. (2017). Towards Personal Learning: Reclaiming a role for humanity in a world of commercialism and automation. https://www.downes.ca/files/books/Toward%20Personal%20Learning%20v09.pdf

Dron, J. (2013). Soft is hard and hard is easy: learning technologies and social media. *Open Journal, 13*(1), 32-43. http://doi.org/10.13128/formare-12613

Duan, J. J., Xie, K., Hawk, N., Yu, S., & Wang, M. (2019). Exploring a personal social knowledge network (pskn) to aid the observation of connectivist interaction for high and lower forming learners in connectivist massive open online courses. *British journal of educational technology*, *50*(1), 199-217. https://doi.org/10.1111/bjet.12687

Durant, K. T., Mccray, A. T., & Safran, C. (2012). Identifying gender-preferred communication styles within online cancer communities: A retrospective, longitudinal analysis. *PLOS ONE, 7*(11), e49169. http://doi.org/10.1371/journal.pone.0049169

Guo, Y. J., Chen, L., Xu, L., & Gao, X. F. (2020). Social network characteristics of learners in connectivist learning. *Distance Education in China*, *2*, 32-39+67+76-77. https://doi.org/10.13541/j.cnki.chinade.2020.02.004

Kellogg, S., Booth, S., & Oliver, K. (2014). A social network perspective on peer supported learning in MOOCs for educators. *The International Review of Research in Open and Distributed Learning, 15*(5), 263–289. https://www.webofscience.com/wos/alldb/full-record/WOS:000347627100011

Kossinets, G., & Watts, D. J. (2006). Empirical analysis of an evolving social network. *Science*, *311*(5757), 88-90. https://doi.org/10.1126/science.1116869

Lazarsfeld, P. F., & Merton, R. K. (1954). Friendship as a social process: A substantive and methodological analysis. In M. Berger (Ed.), Freedom and control in modern society (pp. 18–66). New York, NY: Van Nostrand.

Liang, Y. Z. (2018). Evaluation of individual importance in online interactive networks and its impact on learning outcomes. *China Educational Technology*, *11*, 94-102. https://doi.org/10.3969/j.issn.1006-9860.2018.11.014

Liu, Q. T., Zhang, N., & Zhu, J. J. (2018). Social network analysis of collaborative knowledge construction in teacher workshops. *Distance Education in China, 11*, 61-69+80. https://doi.org/10.13541/j.cnki.chinade.20181108.004

McPherson, M., Smith-Lovin, L., & Cook, J. M. (2001). Birds of a feather: Homophily in social networks. *Annual Review of Sociology*, *27,* 415-444. https://doi.org/10.1146/annurev.soc.27.1.415

Ripley, R. M., Snijders, T. A. B., Boda, Z., Voros, A., & Preciado, P. (2015). Manual for SIENA (version May 22, 2015). Oxford: University of Oxford. https://www.stats.ox.ac.uk/~snijders/siena/RSiena_Manual.pdf

Rogers, P. J. (1995). *Diffusion of innovations* (4th ed.). New York, NY. Free Press.

Siemens, G. (2005). Connectivism: A learning theory for the digital age. *International Journal of Instructional Technology and Distance Learning, 2*(1), 3-10. http://www.hetl.org/wp-content/uploads/gravity_forms/2-298b245759ca2b0fab82a867d719cbae/2013/01/Connectivism-hand-out.pdf

Snijders, T. A., van de Bunt, G. G., & Steglich, C. E. (2010). Introduction to stochastic actor-based models for network dynamics. *Social Networks*, *32*(1), 44–60. https://doi.org/10.1016/j.socnet.2009.02.004

Song, X. F., Zhao, W., Gao, L., & He, C. L. (2014). Content analysis and social network of knowledge sharing in question and answer sites: Taking Zhihu community “online education” topic as an example. *Modern Educational Technology*, *24*(6), 70-77. https://wenku.baidu.com/view/139b54bdbc1e650e52ea551810a6f524cdbfcbc7.html

Waite, M., Mackness, J., Roberts, G., & Lovegrove, E. (2013). Liminal participants and skilled orienteers: Learner participation in a MOOC for new lecturers. *Journal of Online Learning and Teaching*, *9*, 200–215. http://jolt.merlot.org/

Wang, Z., Anderson, T., & Chen, L. (2018). How learners participate in connectivist learning: an analysis of the interaction traces from a cMOOC. *International Review of Research in Open & Distance Learning*, *19*(1), 44-67. https://www.webofscience.com/wos/alldb/full-record/WOS:000428755100004

Wang, Z., Walther, J. B., Pingree, S., & Hawkins, R. P. (2008). Health Information, Credibility, Homophily, and Influence via the Internet: Web Sites Versus Discussion Groups. *Health Communication, 23*(4), 358-368. http://doi.org/10.1080/10410230802229738

Wang, Z. H., Xie, Y. Y., & Li, F. (2012). A study on “educational technology” microblog circle based on social network analysis. *Modern Educational Technology*, *22*(5), 83-87. https://wenku.baidu.com/view/8f86ab2d4b649b6648d7c1c708a1284ac9500551.html

Wang, Z. J., & Chen, L. (2017). Conceptual interaction and learning assessment in distance learning. *Distance Education in China*, *12*, 12-20+79. https://doi.org/10.13541/j.cnki.chinade.20171222.008

Wu, J., Chen, J., & Jin, M. (2016). Analysis of evolution of interactive patterns in blended collaborative learning. *Journal of Distance Education*, *34*(1), 61-68. https://doi.org/10.15881/j.cnki.cn33-1304/g4.2016.01.007

Wu, J., Li, S. S., Zhou, L. S., Shi, L., & Chen, J. (2017). Research on dynamic evolution of user’s relationships network in online health community based on stochastic actor-oriented model. *Journal of the China Society for Scientific and Technical Information*, *36*(2), 213-220. https://doi.org/10.3772/j.issn.1000-0135.2017.02.012

Xu, Y. (2020). Research on the relationship between individual Status in social network and corresponding concept network characteristics in cMOOC. (Master’s dissertation, Beijing: Beijing Normal University). http://etd.lib.bnu.edu.cn/Detail?dbID=5&dbCode=ETD1&sysID=76127

Xu, Y., & Chen, L. (2019). Research on the relationship between individual social network status and corresponding concept network characteristics in connective learning: a partial analysis of interaction in a cMOOC. *Distance Education in China*, *10*, 9-19+51+92. https://doi.org/10.13541/j.cnki.chinade.2019.10.003

Xu, Y., & Du, J. (2021). What participation types of learners are there in connectivist learning: an analysis of a cMOOC from the dual perspectives of social network and concept network characteristics. *Interactive Learning Environments*, 1-18. https://doi.org/10.1080/10494820.2021.2007137

Yang, D., Sinha, T., Adamson, D., & Rosé, C. P. (2013). Turn on, tune in, drop out: Anticipating student dropouts in massive open online courses. Paper presented at the NIPS Data-Driven Education Workshop, Lake Tahoe, NV. https://www.researchgate.net/publication/266203181_Turn_on_Tune_in_Drop_out_Anticipating_Student_Dropouts_in_Massive_Open_Online_Courses

Zhang, J. J., Skryabin, M., & Song, X. W. (2016). Understanding the dynamics of MOOC discussion forums with simulation investigation for empirical network analysis SIENA. *Distance education*, *37*(3), 270-286. https://doi.org/10.1080/01587919.2016.1226230

Authors

Yaqian Xu, is a PhD student majoring in distance education in Beijing Normal University, China. Her research interests include connectivism, online learning analysis, and instructional interaction and she has published 10 papers in journals. Email: xyq_sky@126.com

Junlei Du, is a graduate student majoring in software engineering in Beijing Jiaotong University. His research interests include knowledge graph, data analysis and machine learning and he has published 7 papers in journals. Email: junlei007.love@163.com

Canadian Journal of Learning and Technology
La Revue canadienne de l'apprentissage et de la technologie

Volume 48 (4) Special Issue 2022

Cognification in Teaching, Learning, and Training

La cognification dans l'enseignement, l'apprentissage et la formation

***Vivekanandan Kumar**, Athabasca University, Canada*
***Mohamed Ally**, Athabasca University, Canada*
***Avgoustos Tsinakos**, International Hellenic University, Greece*
***Helmi Norman**, Universiti Kebangsaan Malaysia, Malaysia*

Abstract

Over the past decade, opportunities for online learning have dramatically increased. Learners around the world now have digital access to a wide array of corporate trainings, certifications, comprehensive academic degree programs, and other educational and training options. Some organizations are blending traditional instruction methods with online technologies. Blended learning generates large volumes of data about both the content (quality and usage) and the learners (study habits and learning outcomes). Correspondingly, the need to properly process voluminous, continuous, and often disparate data has prompted the advent of cognification. Cognification techniques design complex data analytic models that allow natural intelligence to engage artificial smartness in ways that can enhance the learning experience. Cognification is the approach to make something increasingly, ethically, and regulatably smarter. This article highlights how emerging trends in cognification could disrupt online education.

Keywords: Cognification, AI in education, Fourth industrial revolution, Educational technology

Résumé

Au cours de la dernière décennie, les possibilités d'apprentissage en ligne ont augmenté de façon remarquable. Les apprenants du monde entier ont maintenant un accès numérique à un large éventail de formations d'entreprise, de certifications, de programmes universitaires complets et d'autres options d'éducation et de formation. Certaines organisations combinent les méthodes d'enseignement traditionnelles avec les technologies en ligne. L'apprentissage hybride génère d'importants volumes de données concernant à la fois le contenu (qualité et utilisation) et les apprenants (habitudes d'étude et résultats d'apprentissage). En conséquence, la nécessité de traiter correctement des données volumineuses, continues et souvent divergentes a entraîné l'avènement de la cognification. Les techniques de cognification conçoivent des modèles d'analyse de données complexes qui permettent à l'intelligence naturelle de mobiliser l'intelligence artificielle de manière à améliorer l'expérience d'apprentissage. La cognification est l'approche qui consiste à rendre quelque chose de plus en plus intelligent, de manière éthique et régulée. Cet article souligne comment les tendances émergentes en matière de cognification pourraient bouleverser l'enseignement en ligne.

Mots-clés : Cognification ; IA dans l'éducation ; quatrième révolution industrielle ; technologie éducative

Introduction

The agricultural revolution and three subsequent industrial revolutions, aided by advancing communication channels, enabled societies to transform (Yusuf et al., 2020). Their paces of adoption allowed societies to accommodate the disruptive changes that the innovations brought. The agricultural revolution, the slowest one and a precursor to the industrial revolutions, spread as foragers started to adapt the domestication of animals and associated farming methods. The first industrial revolution introduced the mechanization of goods production and spread at a pace afforded mainly by roads and railroads using steam-powered machines. The second industrial revolution brought electrification and assembly-line mass production of goods to societies at a pace associated with electrical connectivity networking. The third industrial revolution electronified and computerized societies at the pace of telephonic and early-Internet communication. The fourth industrial revolution, currently ongoing, percolates our societies at the pace of light, afforded by the Internet aided by Li-Fi and Fibre optic networks, and with the anticipated pace of quantum computational power. The increasing pace of technology adoption across the globe puts societies-at-large at a disadvantage because associated technologies become available and used by certain communities within societies without a proper, commonly understood vetting process. Societies are struggling to grasp, adapt, and accommodate the inventions of the fourth industrial revolution. Governance structures are still being conceived as an afterthought. Ethicality of the fourth industrial revolution is still being studied while the application of the fruits of the revolution are already in the marketplace. These challenges are being felt across several industries, particularly in education.

In recent years, higher education has noticeably felt the influence of the phenomenal growth of the fourth industrial revolution (4IR), aided by the associated technologies and theories that are paving new pathways for educators to conceive novel competencies for learners (Penprase, 2018). Nevertheless, technologically feasible paradigm shifts in higher education will still require thorough analysis of efficacy, ethicality, and merit. This article provides one such analysis. From several points of view, it offers a synthesis to explore a possible marriage of intelligent computing and educational services in a way that properly fuses comparably smart, companion entities to almost everything in human learning. Additionally, this synthesis demonstrates the centrality of data - data about the content, data about the interactions with the content, data on the learning community, and data about the learning outcomes. Rich datasets can be analyzed purposefully and ethically to enrich and personalize student learning experiences.

Cognification in Education

Several trustworthy organizations, media, and individuals (Gysegom et al., 2021; Schwab, 2017) have urged the world of education to explore and accommodate the fruits of the 4IR. They urge educators to prepare learners for a future of cognification. Cognification is a major outcome of the 4IR where just-in-time solutions to day-to-day tasks faced by humans arrive on demand, similar to the way electricity flows instantaneously through wires to places of need. The following two examples of cognification illustrate the changing learning landscape under the influence of 4IR innovations.

Consider the scenario where a student needs to perform a literature review on a certain hypothesis. At present, it is a mundane process of collecting literature manually. The student could either use a script to search various databases for relevant literature or collect literature from other researchers in a research group, who had performed similar manual searches in the past. Subsequently, the student could read through the collected literature, discuss various points of views with other researchers, and eventually arrive at a synthesis. A cognified alternative to this manual process of literature review would comprise of at least the following: (1) a list of relevant literature would be made available on-demand, and scripts that are continually collecting and classifying published literature through a gateway accessible from a globally indexed collection of literature. Thus, the student may be left with only the manual task of picking a subset of the literature. (2) analysis would be conducted on how selected literature relates to the hypothesis created on-demand. That is, relations explored and possibly causated or correlated in individual publications would be selected, collated, and connected with the proposed hypothesis. This would allow the student to manually sift through various classifications of the derived relations and manually select the ones that closely relate to the proposed hypothesis. (3) the student could infer several conclusions and multitudes of syntheses arising from the analyses of the selected literature, on-demand. That is, the conclusions of selected literature and the rigour of these conclusions could be automatically inferred, yielding several potential syntheses. The student could then perform a manual search through these candidate syntheses and select one or more that are plausible. (4) a gap analysis of the hypothesis vis-à-vis the leading-edge of the knowledge frontier could then be derived, on demand. While a synthesis does include substantiation in terms of the validity of the associated relations, the student would be tasked to manually identify a derived synthesis or fuse a subset of candidate syntheses into a derived synthesis. That is, artificially smart technologies could supplement the manual natural intelligence of a researcher, replacing the traditional labor component of collecting, reading, comprehending, and synthesizing the manual literature review with a cognified one (Wagner et al., 2022). The combination would support deeper and richer research exploration. As such, the focus of such a cognified solution would mostly supplement the creative side of natural intelligence, offloading the mundane manual labour imposed on the human brain.

Another example of cognification in education could be a scenario where a student was seeking to develop policy recommendations to a provincial government on a particular communicable disease. In this case, a cognification solution comprised of the following could provide, on demand – the relevant literature, a compilation of hypotheses and relations, plausible syntheses, a comparative analysis of policies on communicable diseases from similar jurisdictions, and importantly, a set of research methods to study the implications of candidate policies conceived by the student. That is, the student would simply be expected to create new policy statements or extend existing policy statements after vetting the intermediate inferences offered by the cognified solution. Further, the cognification solution could offer testable models, verified datasets, and potential conclusions. Thus, cognification could supplement and reduce mundane human work. Relieved of this, the student would be free to tackle larger-scale, creative challenges.

Cognification is the art of making something increasingly, ethically, and regulatably smart. As discussed, cognified literature reviews can be automated using cognification to relieve the student of the mundane and assist the student to delve deeper into the solution space. Such a solution is expected to (1) increase its scope as required and improve its accuracy with more data; (2) be governed by ethical principles pertaining to that specific activity, particularly in accommodating inferences made by the automation mechanism as it derives relations, consolidates synthesis, performs analyses, and avails an open research space; (3) be regulatable by authorities, in terms of proliferation, contextualization and application, prior to unleashing them to the users. As for the second example, the scope of the policy statement could be expanded across jurisdictions as well as across communities to situate the problem for a deeper and smarter understanding; the associated datasets, current policies, mathematical models, and machine learning models can be vetted for privacy and security concerns before being considered for ethical use; the process of inference, the publication of its conclusions, and the predicted policy implications can be presented to the government as open research, thus imbuing complete control over its proliferation, contextualization, and application.

Overall, the current trends in artificial intelligence (AI) and machine learning point to the inevitability of a 4IR-induced paradigm shift in higher education - the marriage of intelligent computing, instructional services, and learner activities (Zawacki-Richter et al., 2019). What needs our attention is the uniqueness of this revolution, different from the earlier agricultural, industrial, and digital revolutions in fusing a comparably smart, non-living entity to almost everything human. Smart companion entities are increasingly becoming an integral (and compellingly necessary) part of many activities we do, and the way we think and create, supplementing the very essence of humanity. A differing viewpoint might project this companion entity as essential to assist humanity to overcome several atrocious problems plaguing our global and local communities. One must study the balancing of these two viewpoints and the associated ethics and regulation. Keeping in mind the ongoing global effort in cognification, educational institutions need to offer informed guidance to the academics, to the researchers, and to the students to prepare them to adapt to this potential future as it percolates through societies.

The rest of the article discusses cognification from different academic lenses. Since 4IR is just at its inflection point and cognification is a new area of study, arguments are based on the authors' expertise and potential outcomes of contemporary studies. Future studies need to be initiated to investigate the efficacy of 4IR in education.

Cognification in Learning and Teaching – An Example

Modern AI techniques that drive cognification are not perfect. Mostly, the lack of quality data causes failure. Alternatively, failure can come from issues around the quality and richness of models. As the world of education becomes more evidence-based and more data-centric, the application of cognification is expected to yield more trustworthy outcomes.

Recent advances in explainable AI (xAI) could unveil the inner workings of the underlying AI techniques (Arrieta et al., 2020; Xu et al., 2019). Arrieta et al. (2020) define xAI as a system that produces details or reasons to make its functioning clear or easy to understand. Teachers and students already access such open xAI models - for instance, students were able to revise their work based on xAI feedback prior to submitting assignments and teachers were able to subject student responses to automatic evaluation of targeted rubrics. xAI techniques could potentially learn from their own explanations, thus leading to the possibility of an autonomous self-improving system. However, at this time in its development, xAI can provide an acceptable level of application when tuned with a human-in-the-loop approach.

The following example in automated essay scoring (AES) highlights the impact of xAI on cognification. Kumar and Boulanger (2020a; 2020b) describe a way to predict the rubric scores of English essays by applying deep learning techniques over a vast range of writing features. Based on thorough analyses of the distributions of rubric score predictions and distributions of resolved versus the rubric scores of human raters, they contend that the rubric scoring models closely approximate the performance of human raters. Their study reveals that rubric score prediction does not directly depend on a few word-count-based written language features (all word-count features were pruned). Many intuitive features were found and selected by each rubric with no dominant features.

The data for this AES system came from a Hewlett-Packard Foundation funded automated student assessment prize (ASAP) contest (Shermis, 2014). Kaggle[1] collected eight essay datasets of student-written essays (D1 – D8) – which students from Grades 7 to 10 from

---

[1] https://www.kaggle.com/c/asap-aes

six different states in the USA had written. The essays range from an average length of 150 to 550 words. Each essay was assessed by two human raters. The raters assessed each essay with a holistic score in the range of 0 to 24 and with scores for the following four rubric elements – ideas, organization, style, and conventions. Each rubric was scored in the range of 0 to 6.

The recent version of this AES used the seventh essay dataset (D7) since a) it contained a larger number of sample essays (1567), b) it had a moderate mean number of words (171) reflecting shorter essays, c) it had both holistic (0-30) and rubric level scores (0-3), and d), it had a higher quadratic weighted kappa value (0.72) indicating substantial interrater agreement. D7 included narrative essays on the topic of 'patience'. While the original training set contained 1567 essays with human scores, the original validation and testing set only contained 894 essays without human scores. That is, the holistic and rubric scores assessed by human raters were only available for the original training set that contained 1567 essays. Thus, the 894 essays in the validation and testing set were leveraged for feature selection. This is fine since feature selection must never be informed by the training set to prevent overfitting of the machine learned model.

The essay samples (1567) were processed by the Suite of Automatic Linguistic Analysis Tools (SALAT)[2] which offered a set of 1592 writing features. A subset of these features was used to predict the four rubrics - ideas and content, organization, sentence fluency, and conventions. The resulting performance of this AES is quite comparable to the human rater scores. On average, the human rater scores were identical 63% of times and adjacent (±1) 99% of times. On the other hand, AES predictions on average, after rescaling to a 0-3 scale, were exact and adjacent (±1) 65% and 100% of times, respectively. To the best of our knowledge, only one study attempted to predict rubric scores using D7 (Jankowska et al., 2018), only one study investigated rubric score prediction on D8 (Zupanc & Bosnić, 2017), and very few AES systems in general predict essay scores at the rubric level (Kumar et al., 2017). Zupanc and Bosnić (2017) reported an agreement level (QWK) of 0.70 on the organization rubric (D8).

Based on thorough analyses of the distributions of rubric score predictions and distributions of human rater rubric scores, the outcomes of the AES revealed that the rubric scoring models closely approximate the performance of human raters. Further, the AES system can increasingly improve its predictions as more essays are fed to the AES. The AES model is ethically shareable with students after informing the teacher of strict ethical guidelines in receiving student AES usage data, interpreting their writing competency in conjunction with their use of the AES, and assigning grades for students' submissions in the context of a human-in-the-loop approach. Data that are fed to the AES system should also be ethically subjected to commonly used fairness metrics (Majumdar et al., 2021; Mehrabi et al., 2021; Verma & Rubin, 2018) using contemporary AI fairness toolkits such as the IBM AI Fairness 360, Microsoft's Fairlearn, Google's What-If, Aequitas, and Scikit-fairness. Finally, the AES system should be

[2] https://www.linguisticanalysistools.org/

fully regulatable. For instance, when the AES marker's performance becomes equivalent to that of the human raters, the teacher-in-the-loop directive should inject additional rubrics to drive students toward better writing competency as well as drive the AES toward increasing smartness. A long-short term memory recurrent neural network with an attention mechanism (Alikaniotis et al., 2016; Dong et al., 2017) could be trained to locate spots in student essays that influence the AES system's decision-making when assigning rubric scores, thus improving the smartness of the AES.

The black box of each rubric scoring model was scrutinized using an xAI system to determine the features and the degree to which they contributed to the determination of rubric scores. A set of the 20 most important features for each rubric emerged, in which at least 15 features were unique to every rubric and did not significantly contribute to the prediction of the other rubric scores.

Figure 1 highlights the workings of explainable AI. There are two images in this figure, each showing the 20 key writing features. Each feature is represented in abbreviated forms. For instance, the 8th feature from the top represents the word-count features indicating the total number of words in the essay; the 13th feature relates to positive adjectives. In addition, each image shows the level of contributions of each feature to individual essays. For instance, the five squiggly lines (three purplish ones and two reddish ones) in the left image in the figure point to five essays, and the contributions of the 20 features to each essay. Those five lines are wobbly because different features of writing contribute to different degrees. The contributions of features could be positive or negative. If positive, the line would move to the right toward better scores. If not, the line would move to the left leading to lower scores.

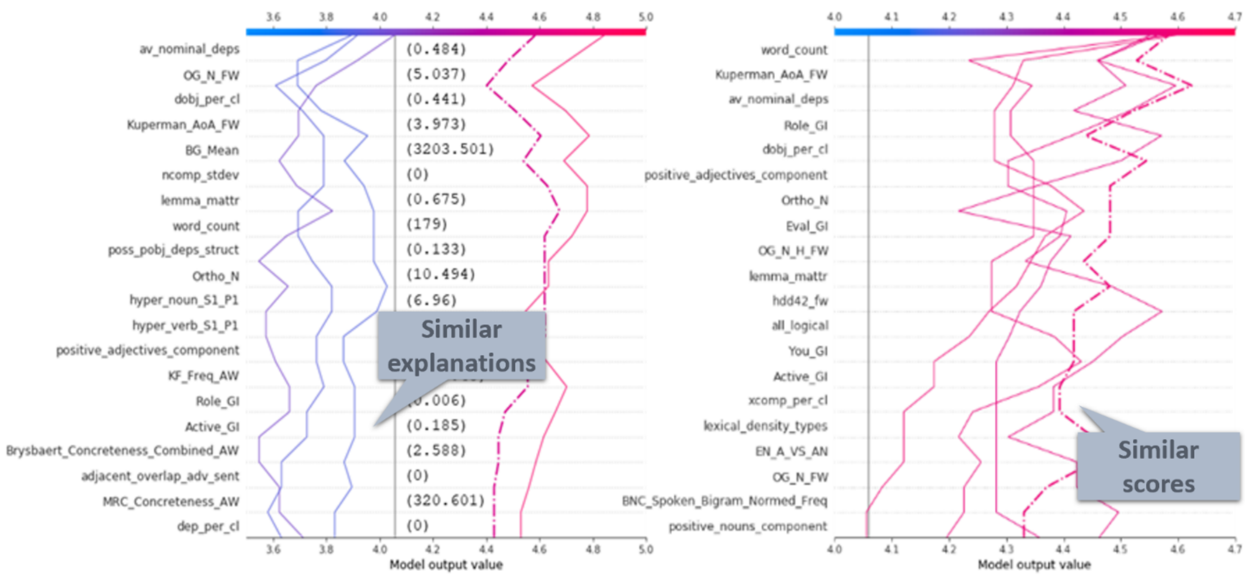
Of the five essays, two of them predict an average score of around 3.9 out of 5.0 while one essay predicts a high score of about 4.8 out of 5.0. Interestingly, these five essays show similar patterns in how features contributed to their predicted scores. One could infer that those students who wrote these three essays have similar writing competencies as well as writing misconceptions. Still, the AES system predicted different final scores for these five essays. Teachers can offer common feedback to such groups and explain how students in such groups can improve their writing competencies corresponding to each writing feature.

The image on the right in the figure points to five other essays where the contributions of writing features on each essay are quite dynamic. That is, the contributions of features are quite varied among the five essays. Despite these variations in contributions of features, these five essays were predicted to obtain a score close to 4.6 out of 5.0. In this case, feedback from the teacher should be more individualized.

Moreover, the study revealed that rubric score prediction does not directly depend on a few features based on word-counts. Many intuitive features were selected for each rubric in the current AES with no specific dominant feature, making it more difficult to trick the AES system. That is, the AES system could identify writing features that students should not ignore. Further, the AES system could also identify to teachers those students who lack competency in these writing features, thus reinforcing the need for a human-in-the-loop approach, and empowering teachers to triangulate their instruction for greater pedagogical outcomes. That is, student essays can be clustered relative to the number of rubric scores, to discover discriminative patterns in the essays that can lead to improved formative and remedial feedback.

Figure 1

Explainable AI in Automated Essay Scoring



Being an xAI-based system, the AES can be applied on a globular scale, across multiple institutions, thus offering a platform for students to compare and/or contrast their performances among a larger group of learners. The AES follows a method that promotes a degree of transparency among users, and an understanding of the AES underlying feature-based deep/ shallow neural networks.

Mechanisms to introduce AI accountability and build trust between AI and human agents are crucial for the reliable and large-scale deployment of AES systems.

Theoretical Model on Cognification

Cognification characterizes smart entities that try to become increasingly, ethically, and regulatably smart. The variables contributing to these traits are identifiable and comparable. Accordingly, they arrive at hypotheses that can lead to a theoretical model on cognification. Further, when cognified entities engage with people in a human-in-the-loop approach, variables of collaboration between the human and the cognified entity arise in terms of sense-making and decision-making.

The traits of collaboration of cognified entities include: i) the control of collaborative interactions in terms of autonomy (e.g., active, ethical, co-regulative), ii) theoretical flavours of collaboration (e.g., socio-constructivist, shared cognitive, etc.), and iii) design of collaborative context (e.g., participants, roles, domains) (Kumar, 1996). Sense-making (Abbass, 2019) enables an entity to a) explore data (e.g., create opportunities to collect new datasets), b) derive data (e.g., create new data from existing datasets), c) interpret data (e.g., longitudinal synthesis), and d) share data (ethically and regulatably). Decision-making (Abbass, 2019) enables it to e) assess opportunities and risks in contexts and situations, f) design, plan, and generate courses of actions, g) select and execute one or more actions, h) reason about and explain the choices made (e.g., causal discovery, trust relations), and i) have a degree of autonomy in executing any of these (i through g) traits of the cognified entity. Cognification of an entity resides at the intersection of its traits of collaboration, sense-making, and decision-making.

Literature defines these traits at various levels of granularity. Sheridan (1992) identified several levels of autonomy. Scholtz (2003) arrived at different types of roles for collaborating partners. For example, Scholtz defines “supervisor”, “operator”, “teammate”, “bystander”, and “mechanic” as the roles for humans in human-robot interactions. Models of self-regulation, from literature (Winne & Hadwin, 1998), and synthesized from literature (Brokenshire & Kumar, 2009), expand the trait of regulation at several granularity levels. The emergence of trust in collaboration between cognified entities has its own levels of granularity (Abbass, 2019; Mohkami et al., 2015).

In summary, theoretical modelling of ‘human in the xAI loop’ is essential for the operationalization of cognified entities in teaching, learning, and training. Cognification is liable to suffer abuse, if such models to govern the creation, the application, and the retirement of cognified entities are missing.

Cognification and the Further Democratization of Education

Presently, educational institutions are responsible for teaching and learning. They enact policies and procedures, under governmental regulations and acts, to offer educational and research experiences. The traditional model of education remains mainstream. However, an underlying movement, akin to research pursuits by private institutions, encourages the pursuit of self-learning (what to learn, e.g., OER textbooks), self-teaching (how to learn, e.g., graduate teaching MOOC), and self-research (e.g., crowd-funded research). This movement, representing a new model of learning and teaching, strives to soften the control of the traditional authorities of education. That is, the contemporary educational institutions are urged to consider offering educational credits obtained, in a reliable and verifiable manner, from non-traditional learning and teaching avenues supported by OERs, MOOCs, learning groups, and so on.

This movement offers evidence of learning by capturing detailed intricacies of student learning experiences, rather than aiming at a credential, such as a degree, as the culmination of student competencies. This evidence can originate either in a traditional educational environment or in a non-traditional environment, where the choice of the environment for a particular competency is left to the discretion of the student rather than the institution.

Students could pick and choose their learning experiences from a variety of learning avenues, compile them into a portfolio of verifiable learning evidence, and demand recognition from credit-offering institutions. Thus, traditional institutions would require new roles to verify learning evidence that comes from a wider variety of learning avenues. Educational institutions do offer such services (e.g., Prior Learning Recognition, Credit Transfer Services) but mostly limited to credits obtained from like-minded institutions or institutions that exist within an accrediting organization (e.g., Middle States Commission on Higher Education). All other learning experiences, not including the ones such as the work-integrated learning or the cooperative learning, which are earned from non-traditional avenues (e.g., free MOOCs) are typically excluded.

A handful of academic institutions have ventured into accepting such learning experiences as micro credentials, but such ventures are still limited to experiences borne out of recognized institutions. Such a restricted credentialing framework is necessitated by the inability of the institutions to verify learning experiences at a global scale in a consistent manner. While there are standards on learner interactions (e.g., xAPI, caliper) and frameworks on experience mapping (e.g., VITAE, ePortfolio), there is no single consistent model that can scale up to verifying learning experiences at a global scale.

Reputation implies higher costs for learners. The average graduate student loan debt balance, as of 2021, is $91,148 among federal borrowers in the United States[3]. The average debt among PhD holders is $159,625; 14% of the average graduate student debt is from the borrower's undergraduate study. The pressure of the cost of education makes quality education unreachable to a significant portion of the global student population. In general, online learning promises to make quality educational experiences equitable but has not measured up, since education quality is still measured mostly in terms of grades and the overall reputation of the institution rather than in terms of quantifiable measures of well-recognized competencies of individual learners. Reputed institutions have a vested interest to maintain the status quo of measuring the quality education. This means that quality education remains accessible to only those students who can afford it, with and without the student debt.

In addition to issues relating to high costs of education, the cognification-based educational movement is further inspired by the fact that traditional ways of teaching, unless carefully crafted, do not naturally inspire creativity, intelligence, and discipline among most students (Astle, 2018). After graduation, student capabilities vary significantly, as the outcomes of education place heavy emphasis on summative evaluation. Formative evaluation captures the process and the experiences of students as they learn and offers a better measurement of learners' capacity than summative evaluations, in general.

---

[3] http://educationdata.org

Blockchain technology can play a vital role in the further democratization of the contemporary education system. Blockchains are immutable ledgers that can record learner experiences at higher levels of granularity, in a continuous manner as and when they arrive. Subsequently, these experiences can be mapped to targeted competencies that match the educational/program/curricular outcomes of students. Employers can seek students targeting specific competencies rather than credentials. Employers can also target self-reliant, lifelong learners. Thus, students can compete on a global scale on specific sets of competencies that interest them, rather than competing to score better grades in tests that offer indirect and abstracted measures of competencies. Because blockchain networks can be reliably shared among all participants, individuals can retrieve past learning activities and continually compile them to expected thresholds. Unlike transcripts, blockchain based learning can continue to accumulate learning credits and growth of competencies as learners progress in the education system. Importantly, privacy and ethical measures on blockchains can be readily enacted through associated technologies (e.g., private blockchains). More importantly, to inspire competition among learners, such a blockchain-based learning trace can be shared publicly, thus helping quality education become truly accessible on a global scale. Institutions can choose to adhere to a blockchain-based framework to supplement existing educational policy frameworks thus accommodating community acceptance of such technologies.

The cost of collecting, analyzing, and maintaining a blockchain-based learning and teaching system is not trivial. At present, the cost of making a transaction in a blockchain is very high. In late 2021, the transaction fee of the Ethereum Blockchain was $2.79695. Blockchain fees depend on several factors including network congestion, transaction confirmation time, and transaction size. Blockchain miners are an important part of this environment, and they stake some of their assets in the blockchain to mine a block. The type of asset depends on the consensus algorithm used by the blockchain in which the transactions are added. Miners are remunerated in the form of block rewards (e.g., new crypto coins) and/or transaction fees to execute a transaction on behalf of the user on the blockchain. For instance, in the Ethereum Blockchain, which currently uses the "Proof of Work" consensus algorithm, miners must solve cryptographic puzzles to mine a block. Once mined, the block can be used to record a learning trace. However, the operation to mine a block requires high-performance computers and a considerable amount of computing power, not to mention the electricity needed to run the high-performance computational devices. The miners must invest heavily to access computational devices. Blockchain is a promising and evolving technology that can record the evidence and the subsequent derivative inferences of learning to further the causes of democratized education provided the underlying cognified operations can ensure consistent improvement, ethical guidelines, and regulatable governance.

Implications of Cognified Education

Cognification is the art of making an entity increasingly, ethically, and regulatably smarter. As the world's complexity grows, humans are discovering that manual methods of the third industrial revolution are inadequate to entirely resolve complex problems, necessitating the need for cognification. Cognified entities are a significant part of the 4IR, especially in the context of education.

Deloitte's fifth annual Global Human Capital Trends report and survey (2017)[4] established that the current half-life of a learned skill, which used to be approximately 25 years, is now roughly 5 years. Deloitte determined that the entire length of a career currently averages 65 years and the tenure in a specific career has reduced to about 4.5 years. That is, people are spending more time in careers and are willing to switch careers more frequently. Accordingly, students need to plan for longer-term learning journeys that continue beyond graduation to reskill and upskill over the course of their conceivably varied careers.

Through this lifelong learning journey, students need to retain traces of their learning as evidence to support their competencies. Such evidence may originate from either traditional and/or non-traditional learning environments. Technologies such as blockchain networks, can assist institutions, employers, and other such agencies to verify the new competencies that students declare. Blockchains networks, while guaranteeing immutability, should be cognified to pave the way for automated mapping of learning traces to estimates of learned competencies. Such a cognified mapping could rely on theoretical support that includes both the human-in-the-loop interactions as well as the supplemental cognification-in-the-loop interactions.

Educational communities in remote and local areas are embracing globalized learning contexts. Consequently, competition for work in geographic locales has become global. Global workspaces expect students to both accommodate cognified tools (as part of their learning journey) and be competent in targeted cognitive capabilities (such as cultural agility and critical thinking).

Research in cognified entities has ventured into several educational areas including AES, software development, music teaching, and industry training. In AES, learners could receive reflective feedback on their drafts and explanation-based feedback on ways to improve their essays. Teachers could personalize instructions targeting writing competencies of specific groups of learners. Institutions could measure overall writing competencies exhibited by learners across different courses, to offer a lens on student writing competencies. Music teaching is increasingly employing cognified entities (e.g., Wirth Method[5]) to measure the impact of teaching music at the school level, classroom level, and individual student level. Energy industries are investing in cognified training programs (e.g., AR/VR immersive training) to empower workers to measure and upskill competencies on their own, in addition to contemporary training requirements of the industry.

---

[4] https://www2.deloitte.com/content/dam/Deloitte/global/Documents/About-Deloitte/central-europe/ce-global-human-capital-trends.pdf

[5] https://wirth-music.org/en/the-wirth-method/

Conclusion

Cognification in learning, teaching, and training raises several important questions. How feasible it is to develop real-world cognified systems for lifelong learning? Could cognification autonomously map learning design and learner activities to an instructional theory such as connectivism? Would the introduction of cognification promote democratization of education? Who owns the copyrights of cognified data as well as cognified models? How intrusive is data procurement in cognified systems? Could cognification offer continuous improvement training to educators? Would cognified tools be accepted in workplaces? What happens if stakeholders do not subscribe to the notion of 4IR in education? Could we truly harness its full potential? How do we transition into a 4IR world while upholding our values on privacy, equality, equity, diversity, and living standards? Currently, cognification lacks the kind of maturity to provide convincing answers to these questions. However, scholars, technologists, and other stakeholders are painting a future of artificial smartness that incorporates human creativity and intelligence, where multiple systems synergize to provide smart support to augmented sense- and decision-making in teaching, learning, and training domains.

References

Abbass, H. A. (2019). Social integration of artificial intelligence: Functions, automation allocation logic and human-autonomy trust. *Cognitive Computation*, *11*(2), 159–171. https://doi.org/10.1007/s12559-018-9619-0

Alikaniotis, D., Yannakoudakis, H., & Rei, M. (2016). Automatic text scoring using neural networks. *ArXiv Preprint ArXiv:1606.04289.*

Arrieta, A. B., Díaz-Rodríguez, N., Del Ser, J., Bennetot, A., Tabik, S., Barbado, A., García, S., Gil-López, S., Molina, D., & Benjamins, R. (2020). Explainable Artificial Intelligence (XAI): Concepts, taxonomies, opportunities and challenges toward responsible AI. *Information Fusion*, *58*, 82–115. https://doi.org/10.1016/j.inffus.2019.12.012

Astle, J. (2018). Do schools really kill creativity? RSA Blog, April 2018. https://www.thersa.org/blog/2018/04/do-schools-kill-creativity

Brokenshire, D., & Kumar, V. (2009). Discovering Causal Models of Self-Regulated Learning. *AIED*, 257–264. https://doi.org/0.3233/978-1-60750-028-5-257

Dong, F., Zhang, Y., & Yang, J. (2017). Attention-based recurrent convolutional neural network for automatic essay scoring. *Proceedings of the 21st Conference on Computational Natural Language Learning (CoNLL 2017)*, 153–162.

Gysegom, W., Houthuys, S., Khanna, S., Migliorini, R., Misljencevic, D., & Robertson, M. (2021). *4IR capability building: Opportunities and solutions for lasting impact*. McKinsey & Company. https://www.mckinsey.com/capabilities/operations/our-insights/4ir-capability-building-opportunities-and-solutions-for-lasting-impact

Jankowska, M., Conrad, C., Harris, J., & Kešelj, V. (2018). N-gram based approach for automatic prediction of essay rubric marks. In E. Bagheri & J. C. K. Cheung (Eds.), *Advances in artificial intelligence* (pp. 298–303). Cham: Springer International Publishing.

Kumar, V. S. (1996). Computer-Supported Collaborative Learning: Issues for Research. *Proceedings of the 8th Annual Graduate Symposium on Computer Science*, University of Saskatchewan, Canada.

Kumar, V. S., & Boulanger, D. (2020a). Automated Essay Scoring and the Deep Learning Black Box: How are rubric scores determined? *International Journal of Artificial Intelligence in Education, 31*, 538-584. https://doi.org/10.1007/S40593-020-00211-5

Kumar, V. S., & Boulanger, D. (2020b). Explainable Automated Essay Scoring: Deep Learning Really Has Pedagogical Value, *Frontiers in Education, 5*. https://doi.org/10.3389/feduc.2020.572367

Kumar, V. S., Fraser, S., & Boulanger, D. (2017). Discovering the predictive power of five baseline writing competences. *Journal of Writing Analytics, 1*(1), 176–226.

Majumder, S., Chakraborty, J., Bai, G. R., Stolee, K. T., & Menzies, T. (2021). Fair enough: Searching for sufficient measures of fairness. *ArXiv Preprint ArXiv:2110.13029*. https://arxiv.org/abs/2110.13029

Mehrabi, N., Morstatter, F., Saxena, N., Lerman, K., & Galstyan, A. (2021). A survey on bias and fairness in machine learning. *ACM Computing Surveys, 54*(6), 1-35. https://doi.org/10.1145/3457607

Mohkami, M., Noorian, Z., & Vassileva, J. (2015). Dynamic credibility threshold assignment in trust and reputation mechanisms using PID Controller. In N. Baloian, Y. Zorian, P. Taslakian, & S. Shoukouryan (Eds.), *Collaboration and technology, 9334* (pp. 148–163). Springer International Publishing. https://doi.org/10.1007/978-3-319-22747-4_12

Penprase, B. E. (2018). The fourth industrial revolution and higher education. In Nancy W. Gleason (Ed.), *Higher education in the era of the fourth industrial revolution* (pp. 208-229). Palgrave Macmillan. https://doi.org/10.1007/978-981-13-0194-0_9

Scholtz, J., & Bahrami, S. (2003). Human-robot interaction: Development of an evaluation methodology for the bystander role of interaction. *SMC'03 Conference Proceedings. 2003 IEEE International Conference on Systems, Man and Cybernetics. Conference Theme - System Security and Assurance (Cat. No.03CH37483)*, *4*, 3212–3217. https://doi.org/10.1109/ICSMC.2003.1244385

Schwab, K. (2016). *The fourth industrial revolution* (First U.S. edition). Crown Business.

Sheridan, T. B. (1992). *Telerobotics, automation, and human supervisory control.* MIT press.

Shermis, M. D. (2014). State-of-the-art automated essay scoring: Competition, results, and future directions from a United States demonstration. *Assessing Writing*, *20*, 53–76. https://doi.org/10.1016/j.asw.2013.04.001

Verma, S., & Rubin, J. (2018). Fairness definitions explained. *Proceedings of the International Workshop on Software Fairness*, 1–7. https://doi.org/10.1145/3194770.3194776

Wagner, G., Lukyanenko, R., & Paré, G. (2022). Artificial intelligence and the conduct of literature reviews. *Journal of Information Technology*, *37*(2), 209–226. https://doi.org/10.1177/02683962211048201

Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated engagement in learning. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 277–304). Routledge.

Xu, F., Uszkoreit, H., Du, Y., Fan, W., Zhao, D., & Zhu, J. (2019). Explainable AI: A brief survey on history, research areas, approaches and challenges. In J. Tang, M.-Y. Kan, D. Zhao, S. Li, & H. Zan (Eds.), *Natural language processing and Chinese computing, 11839* (pp. 563–574). Springer International Publishing. https://doi.org/10.1007/978-3-030-32236-6_51

Yusuf, B., Walters, L. M., & Sailin, S. N. (2020). Restructuring educational institutions for growth in the fourth industrial revolution (4IR): A systematic review. *International Journal of Emerging Technologies in Learning, 15*(3), 93–109. https://doi.org/10.3991/ijet.v15i03.11849

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – Where are the educators? *International Journal of Educational Technology in Higher Education*, 2–27. https://doi.org/10.1186/s41239-019-0171-0

Zupanc, K., & Bosnić, Z. (2017). Automated essay evaluation with semantic analysis. *Knowledge-Based Systems*, *120*, 118–132. https://doi.org/10.1016/j.knosys.2017.01.006

Authors

Vivekanandan Kumar is Professor and Associate Dean of Research and Innovation in the Faculty of Science and Technology at Athabasca University in Canada. His research interests include artificial intelligence in education, cognification, fourth industrial revolution, and learning analytics. http://vivek.LearningAnalytics.ca. ORCID: 0000-0003-3394-7789 Email: vivek@athabascau.ca

Mohamed Ally is Professor in the Faculty of Humanities and Social Sciences at Athabasca University in Canada. His current areas of research include mobile learning and use of emerging learning technologies in education and training. https://news.athabascau.ca/research/athabasca-university-professor-named-commonwealth-of-learning-chair/ Email: mohameda@athabascau.ca

Avgoustos Tsinakos is Professor in the Department of Computer Science of International Hellenic University in Greece. His research interests include mobile learning, technology-enhanced learning, intelligent tutoring systems and internet applications of AI. http://de.teikav.edu.gr/tsinakos/. ORCID: 0000-0001-5043-0226 Email: tsinakos@cs.ihu.gr

Helmi Norman is Associate Professor of the Faculty of Education, Universiti Kebangsaan Malaysia (UKM) or the National University of Malaysia. He is also the Deputy Director of Instructional Technologies of the Center for Teaching and Curriculum Development, UKM. He currently drives the e-learning transformation in the university. His research interests are in the field of digital and futuristic education. https://www.helminorman.com/about Email: helmi.norman@ukm.edu.my

CJLT RCAT
Canadian Journal of Learning and Technology
La Revue canadienne de l'apprentissage et de la technologie

Volume 48 (4) Special Issue 2022

Teaching Architectural Technology Knowledge Using Virtual Reality Technology

Enseigner les connaissances en technologie architecturale à travers la technologie de la réalité virtuelle

Yi Lu, *Athabasca University and Centennial College, Canada*

Abstract

Construction detail (CD) knowledge is one of the leading learning components in architectural technology (AT) study. The traditional pedagogical method adopts a series of two-dimensional drawings to explain three-dimensional objects. The interactive and immersive features of virtual reality (VR) technology attract attention from the educational sector. While architectural design education has begun exploring integrating VR tools in the classroom, especially in the early design stage, AT is one of the very few subjects that have experimented with VR. This research, undertaken from within a larger, ongoing project, aimed to explore if VR could assist in teaching AT knowledge, especially CD. The project has two phases: phase 1 created several VR lessons that explained specific AT knowledge, using a VR technology currently available for educational purposes; phase 2 adopted a mixed method approach to investigate learners' experience with the VR lessons created. This paper focuses on the experience in building up a VR learning environment in phase 1. The initial findings after phase 1 showed that the VR technology adopted in this project was not a perfect tool in creating a VR experience in the CD field but could still offer students degrees of virtual reality learning experience.

Keywords: Virtual reality; Immersive learning environment; Architectural technology; Construction detail

Résumé

La connaissance des détails de construction (DC) est l'un des principaux éléments d'apprentissage dans l'étude de la technologie architecturale (TA). La méthode pédagogique traditionnelle adopte une série de dessins bidimensionnels pour expliquer les objets tridimensionnels. Les caractéristiques interactives et immersives de la technologie de la réalité virtuelle (RV) attirent l'attention du secteur de l'éducation. Alors que l'enseignement du design architectural a commencé à explorer l'intégration des outils de RV dans la salle de classe, en particulier au stade de la conception initiale, la TA est l'une des très rares disciplines à avoir fait des expérimentations avec la RV. Cette recherche, entreprise dans le cadre d'un projet plus large et en cours, visait à explorer si la RV pouvait aider à enseigner les connaissances en matière de TA, en particulier le DC. Le projet comporte deux phases : la phase 1 consiste à créer plusieurs leçons de RV qui expliquent les connaissances spécifiques de TA, en utilisant une technologie de RV actuellement disponible à des fins éducatives ; la phase 2 consiste à adopter une approche de méthode mixte pour étudier l'expérience des apprenants avec les leçons de RV créées. Ce document se concentre sur l'expérience de la création d'un environnement d'apprentissage de RV dans la phase 1. Les premiers résultats après la phase 1 ont montré que la technologie de RV adoptée dans ce projet n'était pas un outil parfait pour créer une expérience de RV dans le domaine du DC mais qu'elle pouvait quand même offrir aux étudiants certains degrés d'expérience d'apprentissage de RV.

Mots-clés : Réalité virtuelle ; Environnement d'apprentissage immersif ; Technologie architecturale ; Détail de construction

Introduction

Virtual reality (VR) technology builds a computer-generated environment that immerses users in a simulated world to play and learn (Bardi, 2019). Virtual reality attracts attention from various spheres of daily life, from healthcare and architectural design to education (Waugh, 2017). Educators, especially in the higher education sector, are starting to enter this uncharted territory by piloting VR experiments to teach certain subjects. For example, VR can create a digitally replicated learning platform that enables students to experience the function of a water pressure system which is traditionally learned through a real-world scenario (Lewington, 2020). However, can VR assist in teaching architectural technology (AT)? The current pedagogy of applying traditional methods to teach complicated AT knowledge poses challenges to learners, specifically new students, in a college-learning environment (multiple sources, personal communication, 2012-2021). This research explored whether one VR technology—EON Reality—could assist in teaching AT in a college's architectural technician/technologist program.

Background Information

Project Context

As a result of architectural practice evolution, AT study generally includes subjects that cover a variety of topics, such as architectural design, building science, and architectural materials (Emmitt, 2013, p. xii).

Traditional Architectural Technology Pedagogy

The conventional and primary learning method in AT education is adopting a series of two-dimensional (2D) drawings to explain a three-dimensional (3D) object. The 2D materials comprise floor plans, building elevations, building sections, construction details (CD), specifications, and perspectives to define a 3D asset. Learners study all 2D materials related to the 3D geometry, envision the 3D asset, and understand various aspects of this 3D object. These aspects include not only the forms of geometry, the shapes on different surfaces, and the spatial relationships among multiple edges (Ching, 2015), but also the technical characteristics of different materials that form the 3D object and various construction techniques.

Architectural Technology Knowledge

As proposed by Wienand (2013), architectural technology can be identified in the following expressions: “the components we accumulate into buildings; that process of accumulation also known as building; the understanding of how to put them together; how that building eventually functions” (p. 11). Wienand (2013) explained that AT’s core task is to “produce architectural details, essentially the design of joints” (p. 12). Wienand (2013) further elaborated several significant functions of these joints, such as fastening the structures together, tightening various components, controlling the possible movement of parts, and securing the intersection between the interior built environment and external conditions (p. 12).

Simple Configurations.

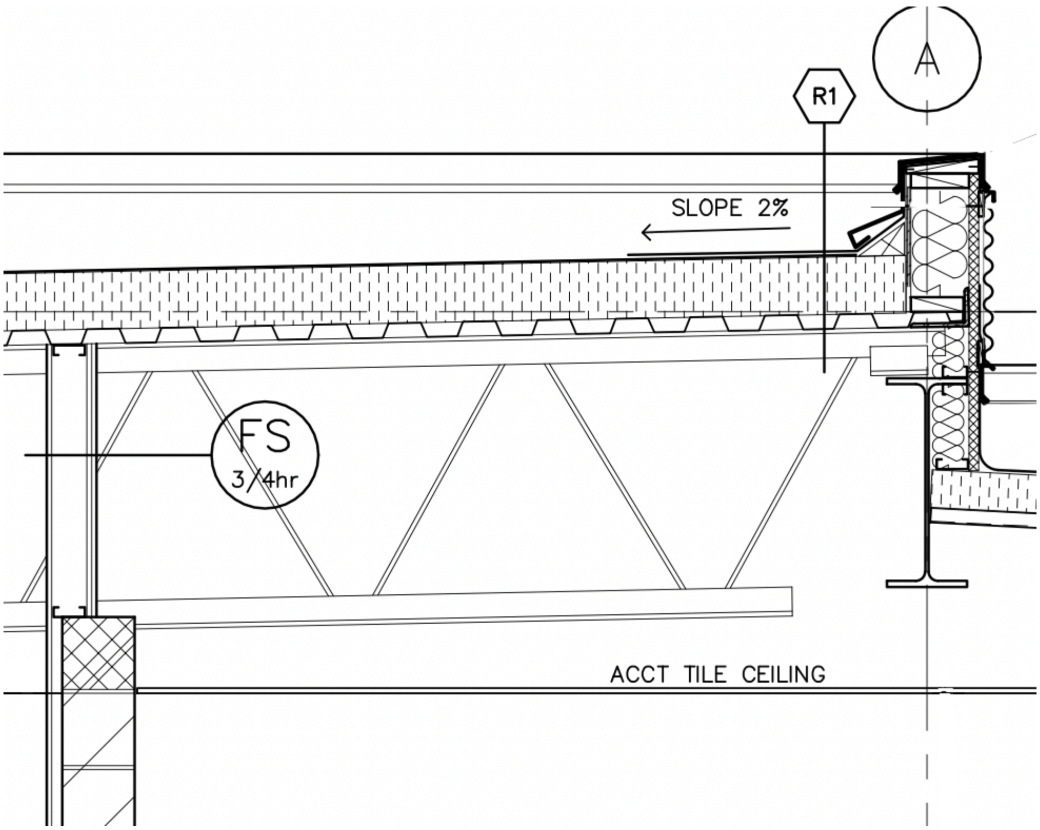
One of the principal learning components in AT is the CD drawing, which specifies a “realistic portrayal of what is to be assembled” (Page & Millar, 2021). One example is studying the composition of a steel roof assembly. This assembly consists of a steel beam, a portion of open web steel joist (OWSJ), a piece of steel deck, a layer of rigid insulation, a sheet of embramine, and a small number of ballasts (Figure 1).

The sole purpose of any drawing is to assist in communicating design ideas as precisely and concisely as possible to different audiences (Walshaw, 2021). Meanwhile, annotations that include technical writing and dimensions are indispensable components in any drawing. Besides sketching various building components for a roof structure composition, Figure 1 also incorporates a series of annotations offering technical information associated with the designed structure elements.

In architectural technology, Figure 1 is a 2D drawing~~s~~ that describes the concept: how a steel roof assembly is constructed. There are however other 2D drawings needed to fully explain the same assembly composition: plan view, elevation view, and CD of this roof assembly. These drawings work collectively to clearly illustrate one roof assembly.

Figure 1

The Detail of Standard Composition of a Steel Roof Assembly in AutoCAD Format



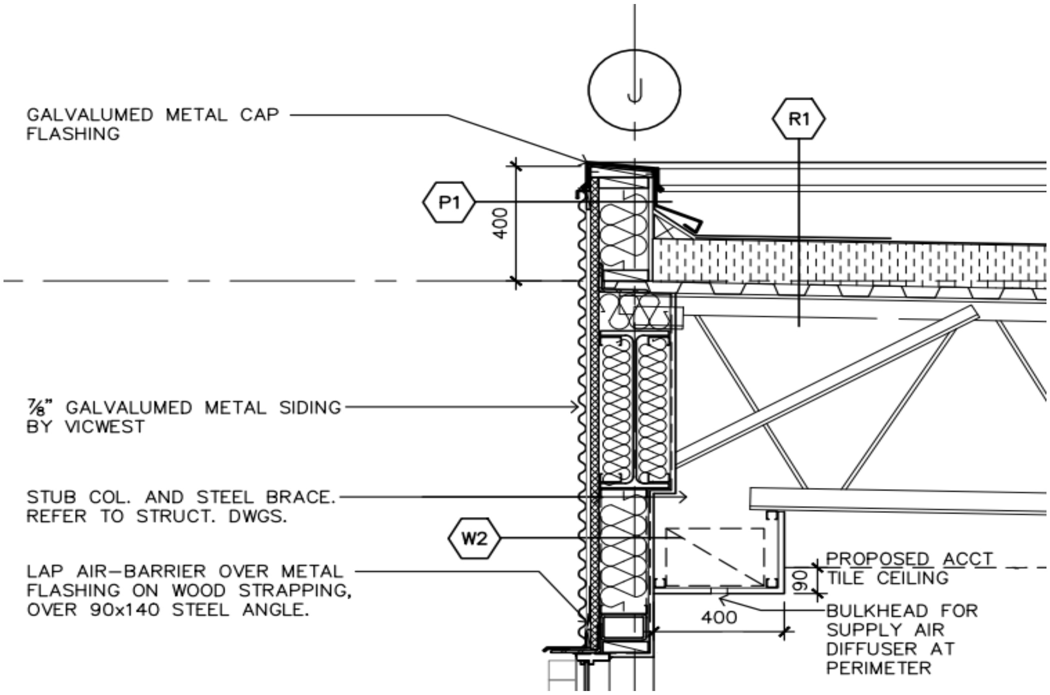
Note. This figure demonstrates the section view of a standard steel roof assembly that consists of multiple layers of materials. As shown in the illustration, the OWSJ is supported by the steel beam, and then the OWSJ supports the steel deck with a layer of rigid roof insulation and 2-ply modified bitumen roofing membrane on top. Together, these materials form the steel roof assembly. The detail symbol R1 indicates the steel roof assembly, with the rigid insulation on top of the steel deck (the rigid insulation is shown as a hatched pattern of broken vertical short lines). Adapted with permission from *Commercial/Industrial Building*, project number 15-002, drawing number A4.05, detail number 1, May 20, 2015, by F. Lapointe, Lapointe Architects.

Complicated Configurations.

Some CD drawings discuss even more complicated concepts. For example, the CD drawing that explains how two assemblies joint together to construct a new intersection is far more complex than the CD drawing that describes only one assembly composition. Figure 2 illustrates how two different assemblies, the roof assembly and the parapet assembly, joint at one point to create a connection near the rooftop.

Figure 2

The CD of a Steel Deck Roof Assembly Joints With a Steel Stud Wall Parapet in AutoCAD Format



Note. The image illustrates a steel deck roof assembly intersects with a steel stud wall parapet in its 2D drawing format, with correct composition of various building materials in the wall assembly and roof assembly. The detail symbol R1 indicates the steel roof assembly, detail symbol P1 represents the parapet wall assembly, and detail symbol W2 specifies the building wall assembly below the parapet. Adapted with permission from *Commercial/Industrial Building*, project number 15-002, drawing number A4.05, detail number 3, May 20, 2015, by F. Lapointe, Lapointe Architects.

Architectural Technology Learning Challenges

It is always challenging to elucidate a 3D object through traditional teaching methods. From a learning perspective, understanding the complicated compositions of various materials and visualizing the real-world assemblies or intersections among different assemblies through 2D methods always challenges students, especially new learners (multiple sources, personal communication, 2012-2021). Many architectural design programs have adopted advanced technologies to educate learners on various topics (Autodesk, n.d.-b). However, AT teaching remains a hard-to-reach area by modern innovations because of the complexity of its knowledge and numerous building materials and building science involved.

Theoretical Position

No architectural technology research project that explores adopting VR in teaching and learning could be found in current scholarly reports. Therefore, it was reasonable to seek inspiration from academic fields closely related to AT. Building construction (BC), while separated from AT by superficial differences, has the same fundamental concept in learning as AT: studying a 3D object through a group of 2D drawings.

Literature Review in the Building Construction Field

In their comprehensive review regarding VR in BC education, Wang et al. (2018) discovered that developments on VR-related applications have been evolving constantly from old-school style to immersive and game-based VR technology. These advancements have benefited “architecture design, construction health and safety, equipment operation and structural analysis” (p. 12). On the other hand, Soliman et al. (2021) questioned certain market-available VR platforms because these technologies seemed to be developed primarily for “VR gaming and not education” use (p. 10).

Still, several groups of BC researchers around the world conducted experiments on applying different VR technologies to teach specific BC concepts. Although these experiments mainly focused on managing site conditions (Davidson et al., 2020; Hasanzadeh et al., 2020; Rahimian et al., 2020), some research projects explored how to construct particular building objects using VR innovation. Abdelhameed (2013) developed algorithms in XML code inside the VR Studio program and initiated a simulative function in an effort to assist learners in selecting the structural elements in the building design and structural design processes (p. 222–223). The VR simulation empowered students to imagine, specifically to study and understand, the 3D forms of the structural elements (p. 227). Meanwhile, Sampaio and Viana (2013) used the EON Studio VR system and 3D models to simulate the construction process steps of bridge decks (p. 2–3). Their research concluded that students could set the construction sequence based on the actual job site process and interact with the virtual models to study “in detail every component of the work and the equipment needed to support the construction process” (p. 5). Two years earlier, Martins and Sampaio (2011) created a simulative and interactive environment through programming software, EON StudioTM, and 3D modeling applications, AutoCAD and 3Ds Max, to describe the launching sequence of a bridge and viaduct construction (p. 51-53). The virtual model illustrated the “complexity of geometry and materials concerning the different elements used in a real work process” (p. 55). In addition, this experiment elaborated a process of “how the different pieces of a construction element mesh with each other and become incorporated into the model” (p. 56). Similar to the previous experiment conducted by Martins and Sampaio in 2011, Bashabsheh et al. (2019) aimed to explain the steps of constructing a two-story house. They experimented using one VR technology, Unity game engine software, and a pair of Autodesk products, AutoCAD and 3ds Max, to create an immersive learning world (p. 716–717). Their project covered topics for the whole contraction process, from surveying the job site, representing stone and masonry works, to detailing the finishing and furnishing (p. 719–720).

Virtual Reality Benefits in Building Construction Learning

Learning materials created in VR are interactive. This interactive method helps learners to visualize how structural elements are constructed and how they relate to one another, thus reducing the confusion caused by the typical 2D-drawing learning format. For example, the interactive annotations in the VR experience connect associated technical knowledge and prompt the learners' responses simultaneously (Abdelhameed, 2013, p. 222; Sampaio & Viana, 2013, p. 3). The users in Abdelhameed's (2013) research confirmed that they "had more clarity on the connections and spatial relationships of the structural system elements while using the VR environment" (p. 226). Moreover, Sampaio and Viana (2013) revealed that learners could interact with virtual building details according to the real-world construction methods, and VR learning enabled the users to "interact in an intuitive manner with 3D space" (p. 4). In addition, Martins and Sampaio (2011) confirmed that to facilitate learning, VR could be integrated into learning material to "allow direct access to any stage of the constructive process" so that learners could navigate to "any point within the virtual scene" (p. 49).

Furthermore, VR lessons significantly improve learner-centered instructional design strategy and increase learning efficiency. Learning materials created through a VR environment meet one of the universal design of learning principles, in which learners are offered multiple means of representation (CAST, 2021). The teaching strategy that combines interactive VR experience and the traditional 2D drawings benefits learners with different learning preferences (University of Waterloo, 2021; VARK, 2021). Additionally, Bashabsheh et al. (2019) proved that VR learning enhanced the learning experience and student satisfaction in teaching building construction courses (p. 723). The researchers discovered that students were more "interested in moving from the traditional way of teaching to other and more efficient teaching methods" and concluded that VR technology was a "good solution to increase the enjoyment of learning" (p. 723).

Possible Solutions for Architectural Technology Education

Although the above-mentioned building construction experiments did not directly relate to AT and the number of such studies is scarce, the experiences learned through these research projects shed light on AT pedagogy. Architectural technology instructors could adopt VR as one of the instructional design strategies to teach specific knowledge.

Learners and instructors consider AT knowledge, especially CD, as the hard-to-understand concept (multiple sources, personal communication, 2012-2021). However, it is challenging to build an actual physical, real-world scale model from a teaching perspective to explain the knowledge and improve learning experience. Hence, a virtual illustration could be an option to save time, space, and cost.

Research Questions

Virtual reality technology enables users to interact with a virtual object in a virtual world while situating them inside a virtual 3D environment to experience the designed object (Bardi, 2019). Therefore, the research questions would be: Can AT, especially CD, be taught using VR? Would learners understand the concepts easier if they were in an interactive simulated environment?

Methods

Research Design

This research project aimed to adopt VR to teach AT knowledge, specifically the CD concepts. This research project has two phases. Phase 1 involves adopting one VR technology to create individual VR lessons that explain specific AT knowledge, such as building envelope assemblies. Phase 2 involves surveying and interviewing voluntary participants to examine their VR experience based on the VR lessons created in phase 1.

This report is about the working experience attained through phase 1.

Project Team at Phase 1

The team consisted of the author of this paper and a group of student research assistants (SRA) from the AT program. When joining this project, SRAs had completed the second-semester study, which discussed targeted AT knowledge, so they understood the specific AT knowledge that would be used to create the VR lessons. Student research assistants participated in this project voluntarily and were required to engage in weekly Microsoft Teams (MST) meeting discussions and submit periodical written reports.

Phase 1 occurred in the summer 2021 semester and lasted for four months. While all SRAs were full-time students in the AT program, many worked part-time, and some worked full-time outside of school simultaneously. As a result, some SRAs could not submit periodic reports on time or had to withdraw from the experiment.

Data Collection and Analysis in Phase 1

Data Collection

The breakthrough of this project came during the summer 2021 semester, and the data reported was collected during this period.

An online MST group was formed for this project to facilitate the project management, and several folders were created under this group to collect documents for various purposes; for instance, a folder was designated for submitting project progress, and another folder was used to host general announcements.

Phase 1 focused on using specific technical features provided by EON Reality to create certain short online VR learning experiments. The content of these short lessons focused on CD knowledge covered in the second semester AT program. Student research assistants were divided into several groups. Each group was responsible for designing one online trial lesson with specific CD knowledge; for instance, a group was assigned to create a lesson that showed a steel deck roof assembly.

Following each MST meeting, one SRA wrote down the meeting brief and posted it to the group’s folders created explicitly for collecting the meeting memos. Every SRA was required to submit bi-weekly progress files along with progressive technical drawing files, where they would write down their reflections about their EON learning experience, and subsequently submit various documents to corresponding folders under the MST group. The analytical data collected during this period included 17 primary folders which harboured a total of 78 progress reports and 170 specific drawing files.

Data Analysis

Data reported in each periodic report and opinions discussed during each weekly meeting were analyzed immediately after each occurrence. Subsequently, a modified action plan was designed, and a discussion about the possible new move was carried out in the following weekly MST meeting. Once clarified and agreed upon by the team, the new strategy would be implemented.

Examples shown in this paper were selected to represent some of the incidents encountered by the team.

Data to be Collected in Phase 2

In phase 2, a mixed methods approach will be implemented. Phase 2 aims to answer the second research question: to explore whether volunteer project participants understand the concepts easier in an interactive simulated VR environment.

A pre-intervention survey will be distributed to volunteer project participants in the same AT program but registered for another academic year. This survey will collect baseline information about AT learners' present learning experience in the architectural program, as well as whether they have VR experience in AT or other academic learning settings. A post-intervention survey will seek feedback from volunteer project participants about their EON-lesson learning experience.

A focus group interview of ten volunteer project participants will be conducted to collect comments about their VR experience. Together, all data collected through the mixed methods approach will be cross-examined.

Justification for Tool Selection

It is expected that this research project will demonstrate one way to save time and money and reduce complications by using existing technologies.

The Virtual Reality Adopted

A market-available VR technology—the EON Reality platform—was chosen based on both the literature review in the BC field and its versatile technical functionalities, such as thousands of pre-made 3D assets, as well as its robust technical support for different academic areas in creating VR lessons for educational use (EON Reality, n.d.-b). EON also allows clients to use their unique 3D assets on its online platform to create VR lessons that convey a tailored immersive learning experience (Lejerskar, 2020).

The 3D Model Creating Software

The core design idea of this research project was to adopt 3D applications in order to create targeted 3D models which were subsequently inserted into one VR technology to generate an immersive learning experience. Architectural technology course instructors have been teaching a 3D modeling software, Revit (Autodesk, n.d.-c), in the major 9-credit design course. Students learn to create architectural building models that include simple structural elements, such as steel beams and steel columns, in the Revit platform. Therefore, adopting an application already familiar to SRAs would decrease the learning curve in this project, and using existing 3D models that included the targeted knowledge concepts could speed up the process and save time in this experiment.

Phase 1 Findings

EON is a superior technology that helps educators create VR lessons in various subjects, with its robust annotations tools and assistance from its technical support team. However, our project team went through several learning curves when creating VR lessons and phase 1 lasted several months because of a variety of issues that could not have been anticipated.

Experimental Virtual Reality Lessons Created

The outputs in phase 1 were remarkable. A large pool of regular progress reports and online digital links to a series of VR lessons targeting specific AT knowledge proved that EON's VR technology offers numerous advantages. The user interface is intuitive, so it is easy to learn and create new content. No coding knowledge is required and various source file formats are accommodated; for example, *rvt (this extension refers to a digital 3D drawing file created and saved in Autodesk's Revit platform) or *skp (this extension refers to a digital 3D drawing model created and saved in the SketchUp software). Final products are conveniently accessible through different external media channels, like YouTube (Chesler, 2019; Richardson, 2015).

Issues Encountered

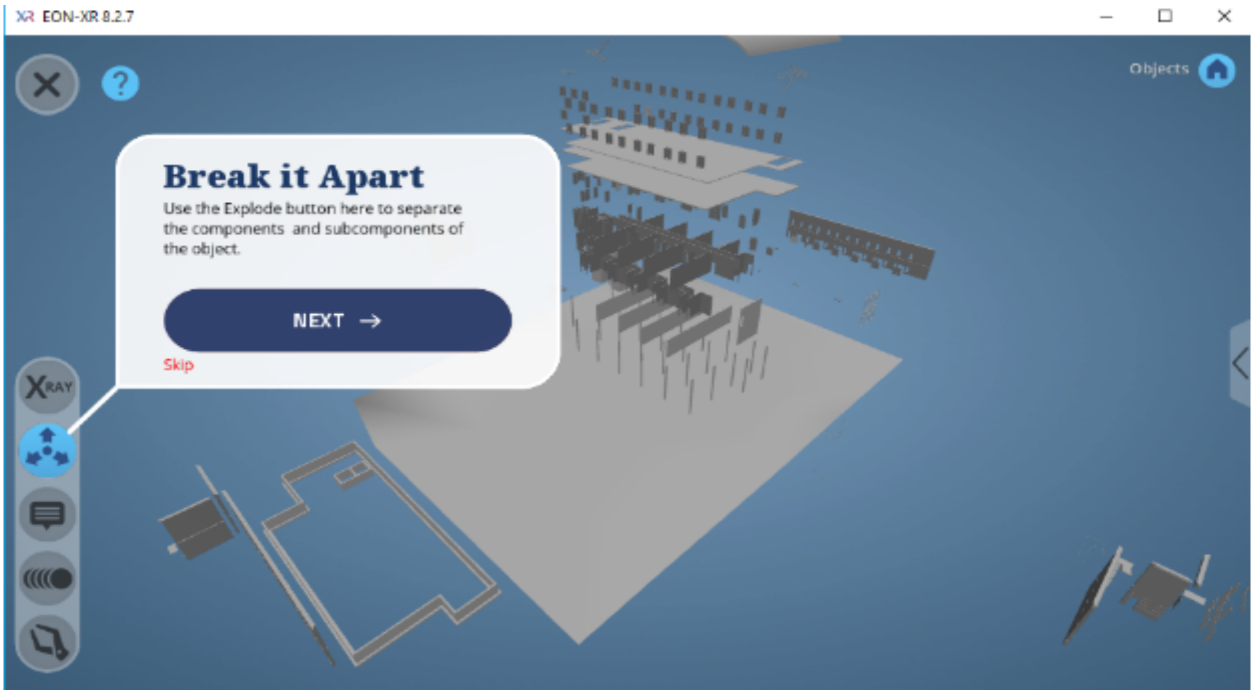
Although EON offers many VR technology advantages, our project team encountered several technical issues.

The First Try-Out

Following the procedure of this research, a previously created Revit model was used. The first try-out was converting the original Revit *.rvt file format into *.fbx (this extension refers to a 3D model saved in the Autodesk Filmbox format) file format that the EON platform could accept. After converting an existing Revit two-story commercial building project, the converted file was imported into the EON platform (Version 8.2.7). The team was amazed by EON's functionality accommodating such a complicated building model; however, it was disappointing that the original colours and material textures on the Revit building model disappeared once the input was completed. Figures 3 and 4 show the model effects pre- and post-input.

Figure 3

The 3D Commercial Building Model in the EON Platform (Version 8.2.7)



Note. The inserted 3D Revit building model has only grey colour in the EON platform, and all building material textures were lost in the data importing procedure. The image, dated March 19, 2021, shows the effect after applying the Explode command. Every item in this model became grey and cannot be identified.

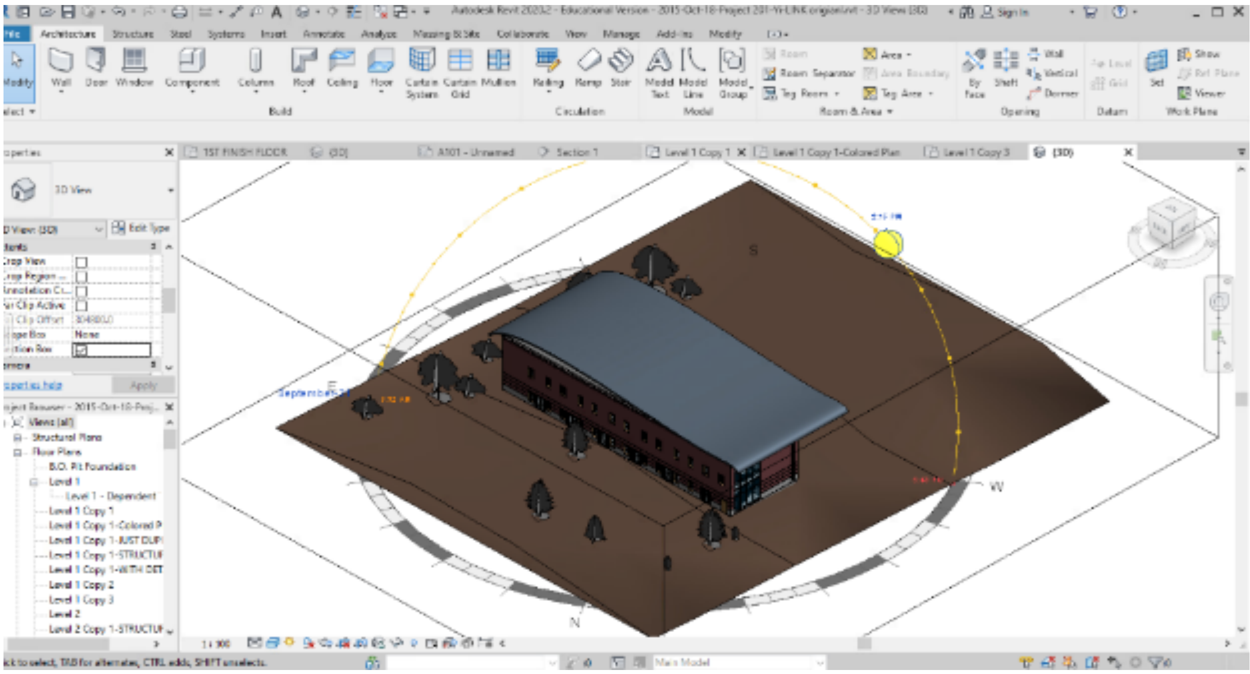
Figure 4 shows the same 3D model created in the Revit application before being imported into the EON application.

One of the many powerful functionalities of Revit software is its building information modeling (BIM) application that is typically used for "creating and managing data during the design, construction, and operations process" (Autodesk, n.d.-a). Users of Revit can choose from thousands of market-available BIM objects that have unique parametric data according to their own project needs and then construct their individual building models. For instance, engineers can select the correct type of steel joist BIM from one manufacturer that provides such a technological tool (Canam Buildings, 2021) and then insert this BIM to form part of the *.rvt structural model.

EON's annotation function performs perfectly in line with Revit's BIM data set. In our experiment, EON's VR platform automatically identified each BIM object from the inserted *.fbx file that originated from the *.rvt file and displayed the name of each structural BIM element on the screen corresponding exactly to its sourced data. However, the 3D assets created in the Revit platform without any generic BIM data could not be identified by EON's annotation function; as a result, manual data entry was required for each of these components. For instance, the curvy silver metal roof in Figure 4 could not be recognized because that was created in the Revit application manually as a generic 3D geometry.

Figure 4

The Same 3D Commercial Building Model in the Original Revit Platform (Version 2021)



Note. The original 3D Revit model has various colours for different building materials, and all material textures in the Revit application are legible. This is the same 3D model as shown in Figure 3 before importing to EON. Image dated March 19, 2021.

The Next Attempt

To explore if material colours and textures from the original 3D models could be maintained when importing to EON, the team experimented with SketchUp *.skp files. Adopting *.skp was a logical choice because: first, the *.skp files represent 3D models generated from the SketchUp software (Trimble, 2017); second, the *.skp file format is recognized by EON (EON Reality, 2020, p. 74); in addition, one of the AT courses taught the SketchUp application, so the project team was familiar with it.

In the experiment, *.skp files that concentrated on various CD knowledges were imported into the EON platform. The results showed that multiple colours could be seen and material textures could be detected. However, since models created from SketchUp ground were not parametric objects, EON's annotation function could not recognize any data, and thus, each annotation needed in the VR lesson had to be input manually.

The Following Try-Out

Understanding that *.skp files could produce excellent results in the EON program encouraged the team to create more useful 3D assets in the SketchUp platform. An online collection wonderland—3D Warehouse (https://3dwarehouse.sketchup.com) where manufacturers, designers, enthusiasts, and community members generate and share diverse SketchUp 3D modeling contents—had been discovered and explored. The search ended with inspiring and eye-opening results: a variety of 3D assets that related to CD were located and downloaded, for instance, the open web steel joist created by an individual (G., 2021) or a "floor ceiling steel-framed" model by a manufacturer (Georgia Pacific Gypsum, 2021). Using existing 3D models accelerated the progress of making 3D CD models for EON VR lesson creation.

The Subsequent Challenge

Useful assets from the 3D Warehouse could be directly imported into the SketchUp platform for advanced editing to match CD knowledge discussed in some AT courses. However, certain *.skp files downloaded from the 3D Warehouse could not be properly uploaded to EON (Lu, 2021a, p. 2). EON's technical support team suggested there might be technical issues in those individual file structures and advised our team to download desired *.skp files and save as *.fbx, or *.dae (this extension refers to the digital asset exchange file) format (M. Kasica, personal communication, March 29, 2021). One of our SRAs discovered a simple solution to this format issue: saving the current 2021 version *.skp model backward to older versions of SketchUp, such as 2017 or 2018, and importing the older version *.skp file to EON (P. Villalba, personal communication, April 1, 2021). This method reduced the project's overall time spent creating 3D models.

More Project Challenge

To prepare the prerequisites for the VR lessons, our team had successfully created several CD *.skp models. For instance, to create an asset that included a masonry wall assembly with a partial poured-concrete foundation in SketchUp, the team first selected existing assets from the 3D Warehouse website and then modified the model by adding components based on the CD knowledge discussed in AT courses. However, these newly created complicated files could not be successfully uploaded to the EON VR platform. Meanwhile, EON had been working on upgrades to a newer version—EON-XR (Version 9.0). It was unclear whether the upgrade process was associated with the file uploading process, but our issue persisted, and the team idled for two months and could not progress as planned (Lu, 2021b, p. 2).

The Biggest Hurdle

The biggest hurdle in working on this project at phase 1 was the ongoing advancement of VR technology. EON's technical development was constantly evolving, and unfortunately, the advancement still could not fix some of the technical issues the project team encountered because of AT knowledge's complexity. This section focuses on some new technological developments and associated problems.

Colours and Textures of Building Materials

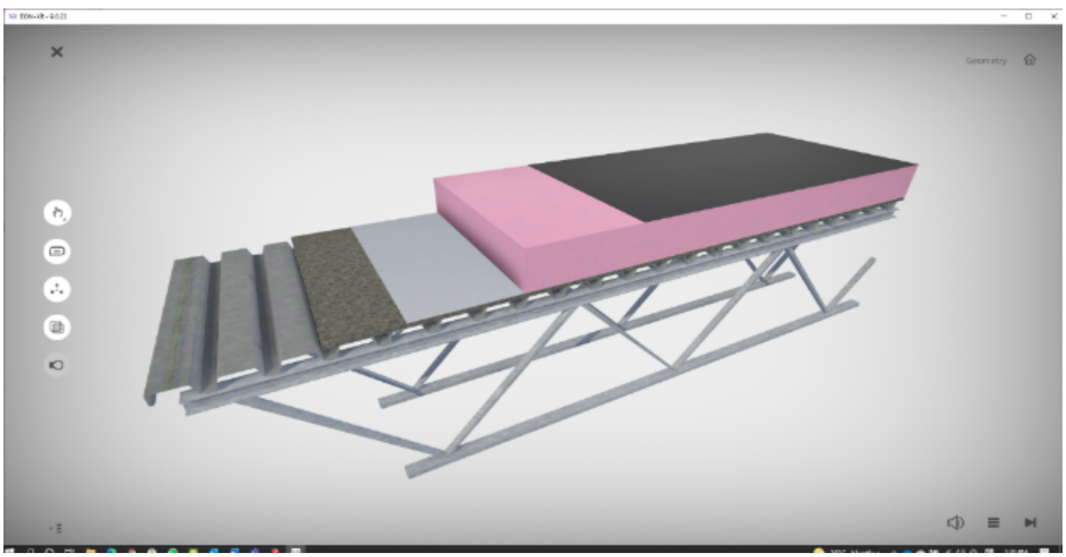
Our team created several VR lessons about specific CDs. However, there were still a few areas where the EON platform could not measure up to the rigor of AT due to the limitations of current VR technology even though the company continued to upgrade. For instance, the hatch colours and material textures on the original 3D model were still discoloured and unnatural after importing into the EON platform, despite using the *.skp file format and importing the model into the newer version of EON (Figures 5 and 6).

Explode Command

An issue persisted when using the explode command. As shown in Figure 7, this *.skp 3D model illustrates a steel deck roof assembly that usually contains stacked layers of materials in a specific order. After exploding this model in the VR platform, the components in the model were dispersed randomly with different orders and directions in space. Figure 8 demonstrates what happened when applying the explode function.

Figure 5

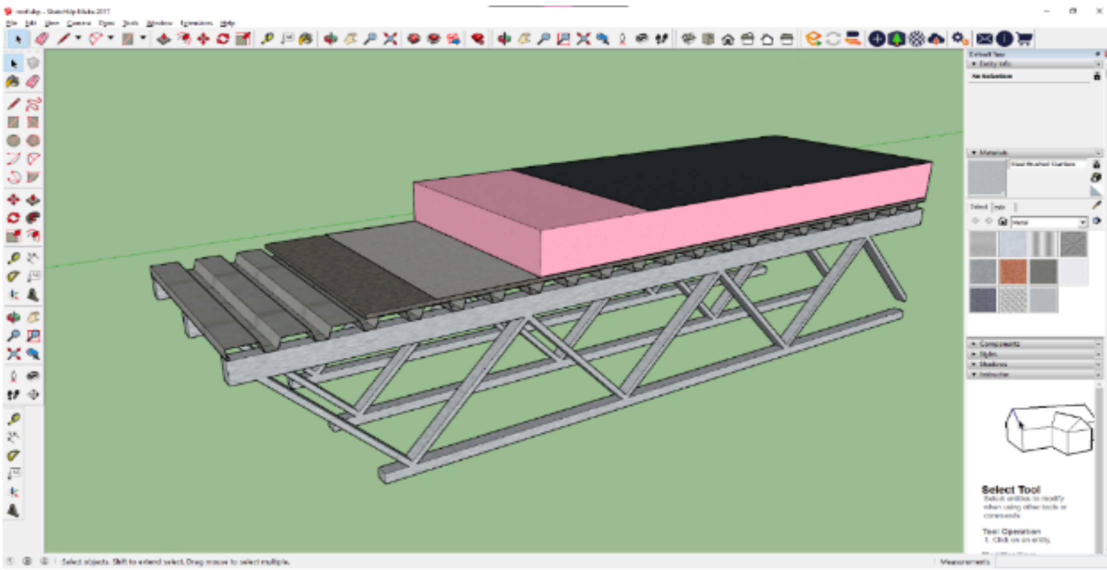
The Steel Deck Roof Assembly 3D CD Model in the EON Platform (Version 9.0.23)



Note. This figure presents the imported roof assembly *.skp model in EON. The effect shows discoloured materials and textures are lost after uploading the file to the EON application. Image dated July 5, 2021.

Figure 6

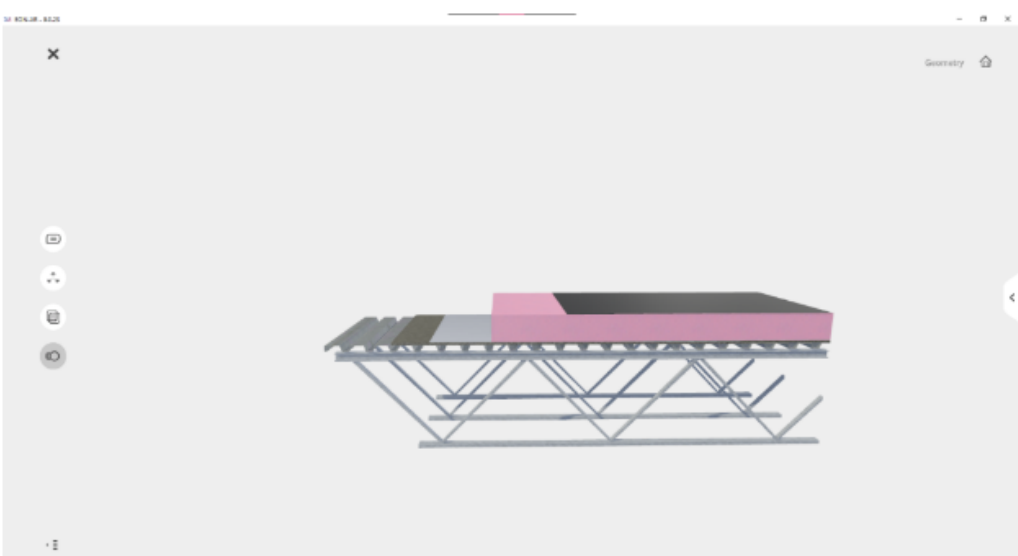
The Steel Deck Roof Assembly 3D CD Model in the SketchUp Platform (Version 2017)



Note. This figure illustrates the original 3D *.skp model in SketchUp that displays the precise colours and textures of various building components. This is the same 3D model shown in Figure 5 before importing to EON. Image dated July 5, 2021.

Figure 7

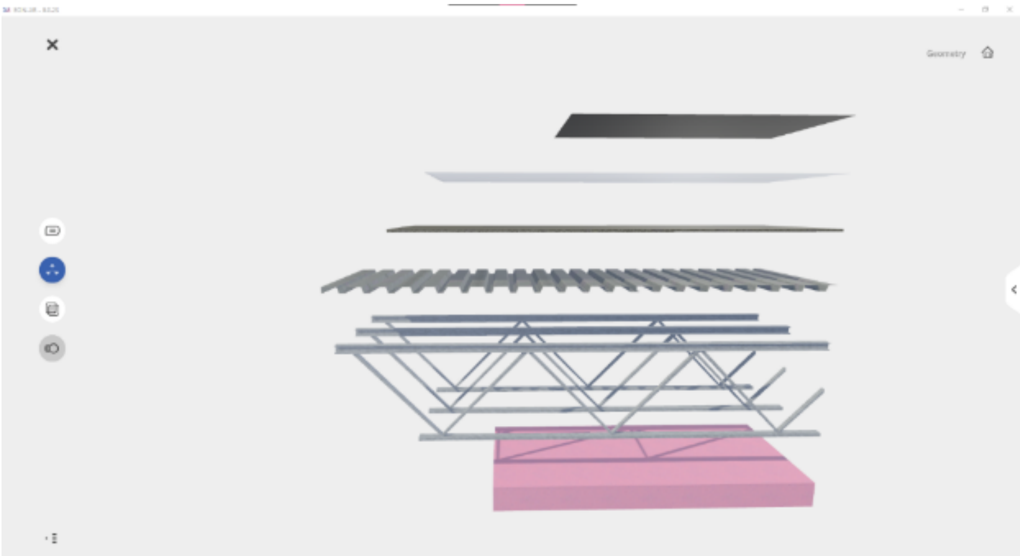
The Steel Deck Roof Assembly 3D CD Model in EON Platform (Version 9.0.23) Before Exploding



Note. This figure demonstrates the imported *.skp model in the EON platform. It maintains the correct order of layers of different building materials before applying the explode command. As shown, the OWSJ supports the steel deck, a layer of rigid insulation (in pink) sits on top of the steel deck, and a layer of the roof membrane is on the very top of this roof assembly. Image dated July 5, 2021.

Figure 8

The Steel Deck Roof Assembly 3D CD Model in EON Platform (Version 9.0.23) After Exploding



Note. This figure presents the effect of the imported *.skp model in the EON platform after applying the explode command. The image exhibits layers of different building materials with imprecise orders and orientations. For instance, the pink piece of rigid insulation is located under the OWSJ. In AT, the rigid insulation should be located on top of the steel deck in order to construct an effective building envelope. Image dated July 5, 2021.

To further explain why the order of building materials is essential in AT learning, let's review one 2D working drawing details that describes the steel deck roof assembly (Figure 9).

In architectural technology learning, the order of the layers of materials in any CD is critical. Building materials not only have their own compatibility with the climate and environment in which the building is located, but also the physical properties of each material and the specific composition of a group of materials impact code compliances and the building energy performance (Crisman, 2017). Figure 9 demonstrates the precise technical knowledge involved in studying a steel roof assembly CD.

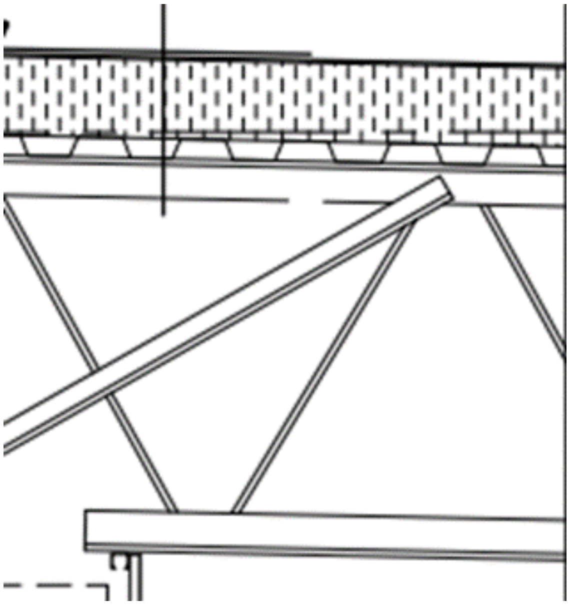
Similarly, Figure 7 shows the correct composition and order of the steel deck roof assembly before applying the explode command in the EON platform. The rigid insulation (the pink layer of material) is located under a sheet of roofing membrane to protect the building occupants from weather conditions outside the building. In comparison, in Figure 8, the rigid insulation has been mistakenly placed under other structural components, so the function of rigid insulation has strayed. As a result, incorrect learning occurs (Lu, 2021c, p. 5).

Annotation Function in Version 9.0

Other than the components being mislocated once the 3D assembly was disassembled, the tags for each element became mixed up and dispersed in different directions. The effect of this is shown in Figures 10 and 11.

Figure 9

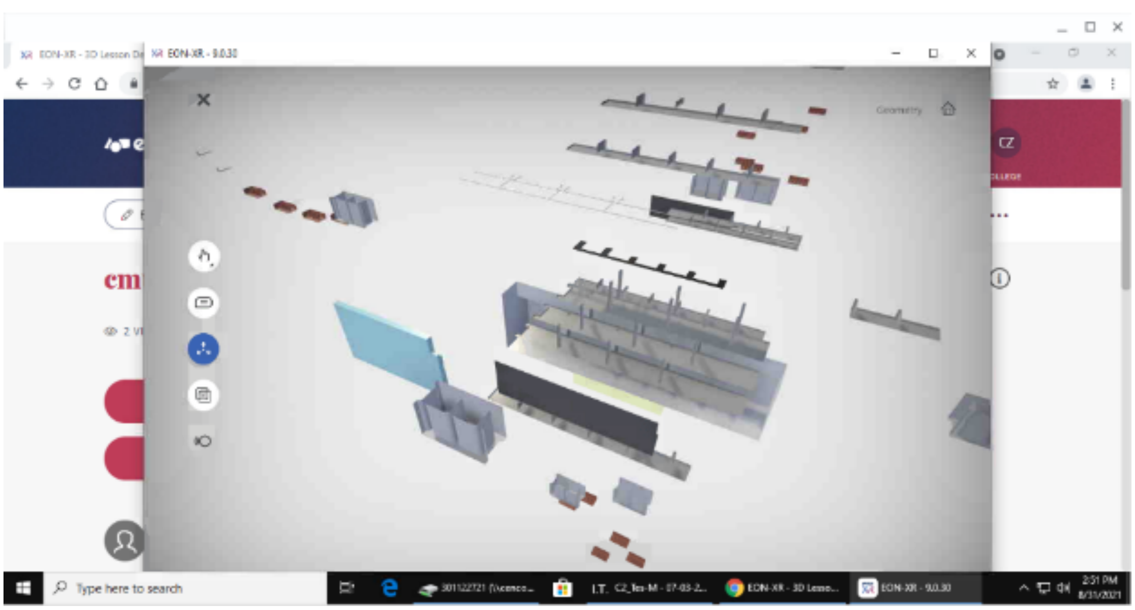
A Zoom-in View of the Steel Deck Roof Assembly CD in AutoCAD Format



Note. The image shows a steel deck roof assembly with the correct order of various roofing components. The drawing shows that the OWSJ supports a steel deck, and a layer of rigid insulation is on top of the steel deck; a final layer of roof membrane finishes the roof assembly. Adapted with permission from *Commercial/Industrial Building*, project number 15-002, drawing number A4.05, detail number 3, May 20, 2015, by F. Lapointe, Lapointe Architects.

Figure 10

The VR Lesson Shown in the Newest Version Before Enabling Annotation Function

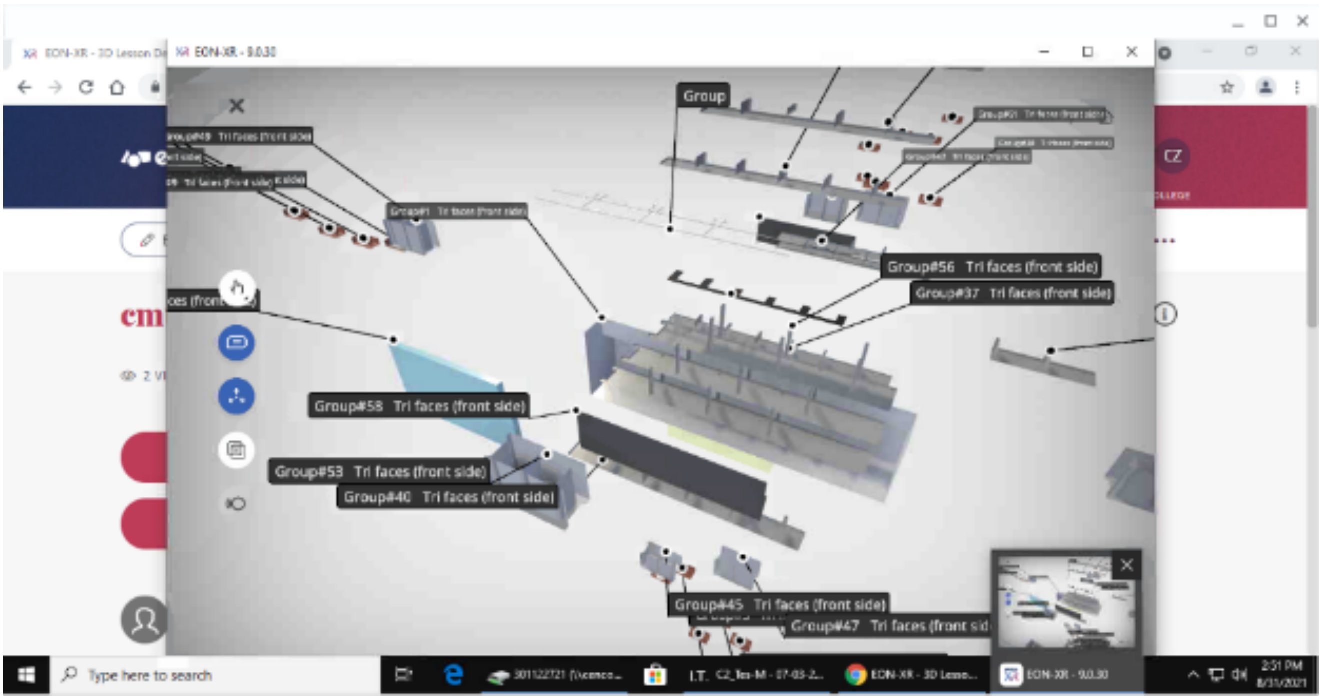


Note. This illustration shows how, before enabling the annotation function, various components dispersed from the brick on the concrete masonry unit wall 3D model after applying the explode command. Image dated August 30, 2021.

Figure 11 shows how various model components link with their own tag after the annotation function has been enabled. In AT's working drawing, as shown in Figure 2, the arrow of the annotation must point to the exact material that the text is referring to in order to make sure there is no misunderstanding or miscommunication among various building professionals, because all annotations in the CD, along with other technical information on the CD drawings, are the primary document used by construction site professionals from different trades (Kubba, 2017, Chapter 13).

Figure 11

The VR Lesson Shown in the Newest Version After Enabling Annotation Function



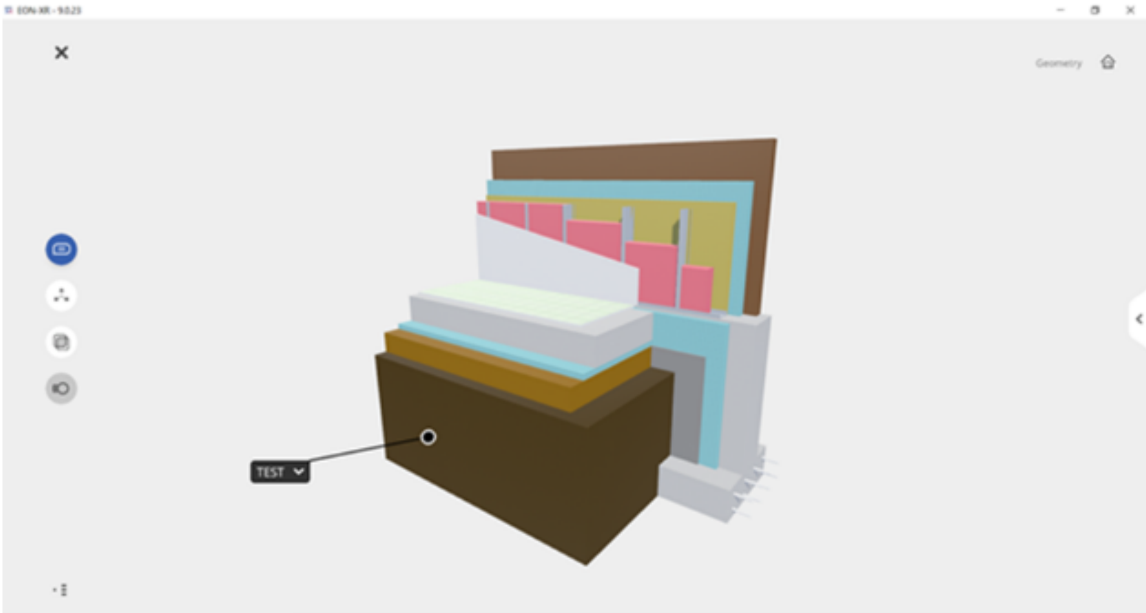
Note. This image exhibits how the tags for different components scattered from the brick on the concrete masonry unit wall 3D model after enabling the annotation function. The lines between text and corresponding components do not reach. Image dated August 30, 2021.

Annotation Function in Version 9.1

The newly released version—EON-XR (Version 9.1)—did not fix the rendering issue that occurred in the older version. Moreover, our team discovered a new problem: the annotations created in the older version vanished. Hence, the team had to re-create all annotations for each VR lesson. This issue is shown in Figures 12 and 13.

Figure 12

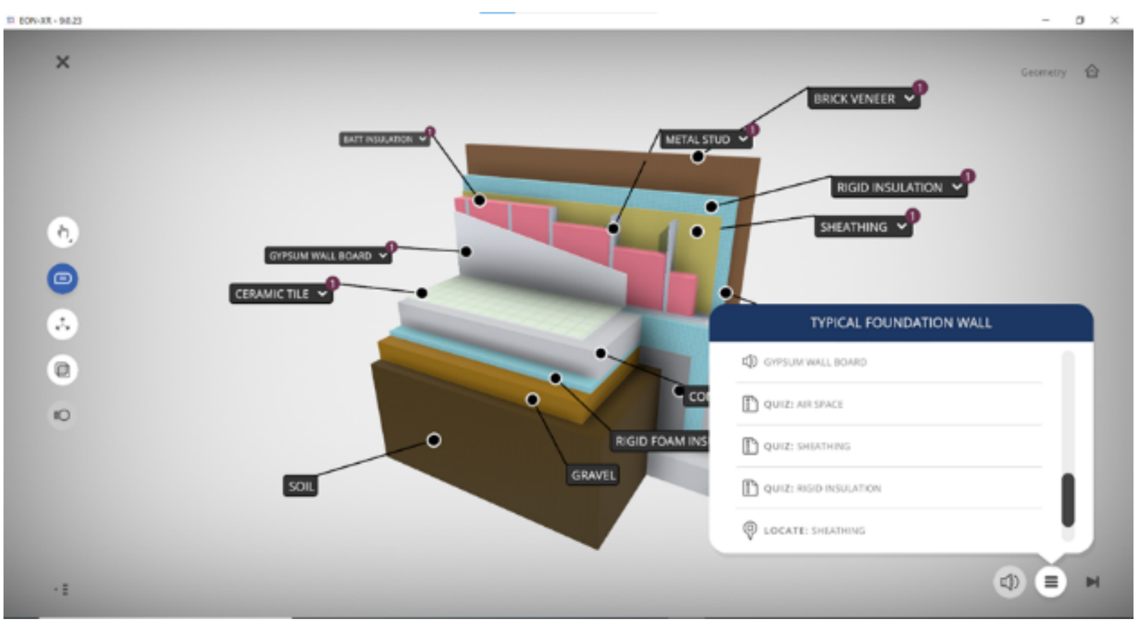
The VR Lesson Created in the Previous Version Displayed in the Newest Version



Note. The image shows how annotations vanish in the newest version. This VR lesson on wall assembly was created from the previous version. Image dated September 3, 2021.

Figure 13

The Re-Created Annotations in the Newest Version



Note. All annotations in this VR lesson, including tags, captions, quizzes, digital voicings, and so on, had to be re-created for the same model shown in Figure 12. Image dated September 3, 2021.

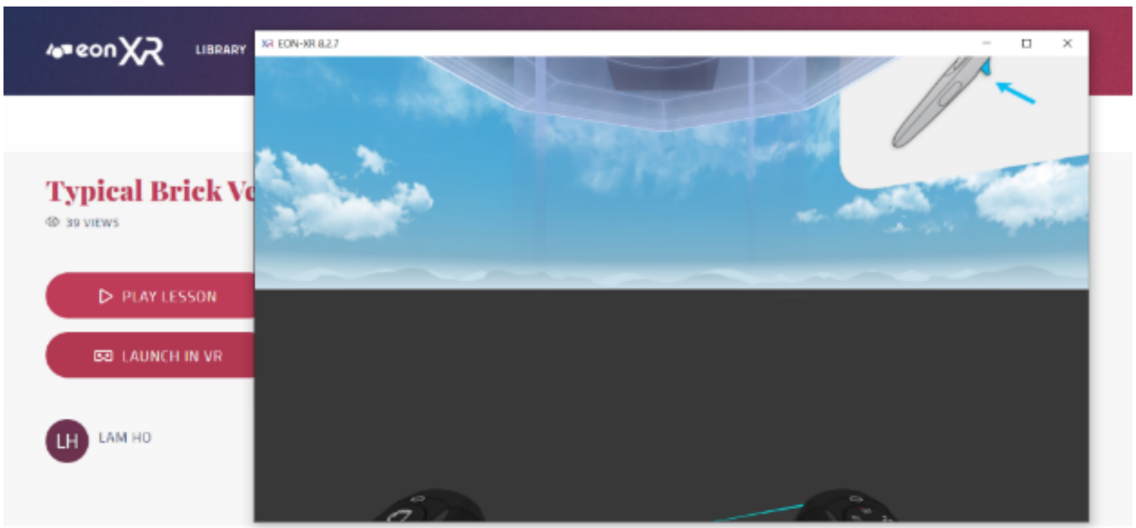
Other Technical Issue

The VR function was perfect when using a desktop in the older version, but this was dropped in the newest version; fortunately, VR function was maintained in the hand-held device format so users could still try out the VR experience on their cellphones.

Figure 14 shows that users can experience the VR function on a desktop computer without a headset, but this function was removed in the newest version of EON.

Figure 14

The VR View in the Older Version of EON (Version 8.2.7)



Note. The image shows one of the screenshots of the VR experience on a desktop computer without the headset. Image dated July 25, 2021.

Discussion

EON Reality is an excellent VR tool to create an interactive learning experience (Lejerskar, 2020). It enables the view and analysis of a 3D object from 360 degrees, both outside and inside, and accepts models created by various applications (EON Reality, 2020, p. 74), accommodating the lesson creator's capability and available resources. EON's annotation function is superb in recognizing BIM data embedded with a 3D asset. For example, in the case of a 3D model built up in the architectural professional software Revit, the data associated with its BIM elements can be picked up by EON's annotation function when making a VR lesson. This function can pinpoint the exact model components linked with BIM parameters and showcase the data automatically and precisely. This feature eliminates the time needed to input all the tags and reduces the possibility of making mistakes when data is entered manually. It significantly speeds up the whole VR lesson creation process and ensures information accuracy.

Even though the project team encountered various barriers when creating VR lessons, the experience gained throughout the phase 1 process was valuable in studying targeted AT knowledge and improving teaching strategies (Lu, 2021c, p. 11). Student research assistants stated in weekly project meetings that working on these VR lessons benefited their own understanding of certain CD concepts, broadened their horizons on specific VR and other emerging technologies, and boosted their competitiveness in the job market (multiple sources, personal communication, July-August 2021). Virtual reality lessons enable users to virtually view the complex AT learning elements and understand the intricate spatial relationships among various components. While 2D drawings certainly are a precise approach to showing technical information, VR can transform the teaching to be more engaging and easy-to-understand.

Conclusion

The Project

Phase 1 of this VR project explored adopting a market-available VR technology to create specific lessons to enable learning certain AT concepts. Although it was not fully completed as per the project schedule due to a combination of factors: the EON platform's ongoing technical development and the funding for this project being for only one calendar year. Phase 2 is currently underway; in this phase, voluntary participants are testing the VR lessons and providing feedback about their VR experience. A mixed method approach will be implemented to investigate participants' quantitative and qualitative responses.

The Virtual Reality Tool

Even though EON Reality is upgrading constantly, its newest version still cannot correctly illustrate particular AT information. In AT, especially in CD study, the order and orientation of different structural and building materials are critical knowledge that does not allow for errors because it involves building science and energy efficiency requirements in building codes. Phase 1 would have achieved more remarkable results if the project could have lasted longer or waited until VR technology advanced to a level that meets the rigor of AT.

Phase 1 of this project confirms that VR technology benefits the learning process. The degree of such benefits depends on the rigor of the knowledge to be represented. It may be true that EON's VR technology works very well in teaching learning concepts in other academic disciplines (EON Reality, n.d.-a); however, its current technological advancement does not meet the standard of AT knowledge. Although the VR lessons created on certain AT concepts provide an interactive and immersive learning environment, VR cannot fully and accurately represent several specific AT topics.

Recommendations

The VR experience in phase 1 suggests that teaching professionals should work closely with technology developers to find solutions as some technological improvements were achieved when our team communicated directly with the VR development technicians. Moreover, the phase 1 study has indicated that the partnership between the application users and the VR technical team is ongoing and evolving. The educators continue taking the training courses provided by the VR platform to improve their VR lesson-building skills. The VR lesson creators should also immediately report any technical problems that emerge while creating the simulative experiences. Furthermore, this study suggests that either the researchers in the AT discipline should find another VR tool for their specific needs, or the current employed VR tool must advance to meet the rigor of AT knowledge. Therefore, more explorations on adopting VR in teaching AT learning should be conducted to advance this field of study.

Acknowledgment

This research project was funded by the Applied Research and Innovation Fund (ARIF) fellowship program from Centennial College. I would like to express appreciation for the funding. I would also like to express gratitude to the School of Transportation at Centennial College for their ongoing sharing of the EON license with our project team members.

Moreover, I would like to thank the EON technicians who worked collaboratively with our team on this project. Their technical assistance undoubtedly improved our VR learning experience. Additionally, I want to thank all student research assistants for their hard work and diligence. I am grateful to Dr. Jordan Wosnick, who oversees all ARIF projects at Centennial College and provided ongoing project management assistance for phase 1 of this research.

Images in this article were created by F. Lapointe (Figures 1, 2, and 9), K. Seo (Figures 5, 6, 7, and 8), C. Zhang (Figures 10 and 11), and S. Alamro (Figures 12, 13, and 14) and were used with permission.

References

Abdelhameed, W. A. (2013). Virtual reality use in architectural design studios: A case of studying structure and construction. *Procedia Computer Science*, *25*, 220–230. https://doi.org/10.1016/j.procs.2013.11.027

Autodesk. (n.d.-a). *BIM benefits. What are the benefits of BIM?* https://www.autodesk.com/industry/aec/bim/benefits-of-bim

Autodesk. (n.d.-b). *Autodesk for educators*. https://www.autodesk.com/education/educators

Autodesk. (n.d.-c). *Revit for architecture. BIM tools for architects.* https://www.autodesk.ca/en/products/revit/architecture

Bardi, J. (2019, March 26). *What is virtual reality: Definitions, devices, and examples.* Marxent. https://www.marxentlabs.com/what-is-virtual-reality/

Bashabsheh, A. K., Alzoubi, H. H., & Ali, M. Z. (2019). The application of virtual reality technology in architectural pedagogy for building constructions. *Alexandria Engineering Journal*, *58*(2), 713–723. https://doi.org/10.1016/j.aej.2019.06.002

Canam Buildings. (2021). *Parametric objects*. https://www.canam-construction.com/en/engineering-tools/parametric-objects/

CAST. (2021). *Principle: Provide multiple means of representation*. https://udlguidelines.cast.org/representation

Chesler, J. (2019, December 13). *EON Reality announces multilingual global update for EON-XR platform*. EON Reality. https://eonreality.com/eon-reality-multilingual-global-update-avr-platform/

Ching, F. D. K. (2020). *Building construction illustrated* (6th ed.). Wiley.

Crisman, P. (2017, February 1). *Materials*. Whole Building Design Guide. National Institute of Building Sciences. https://www.wbdg.org/resources/materials

Davidson, J., Fowler, J., Pantazis, C., Sannino, M., Walker, J., Sheikhkhoshkar, M., & Rahimian, F. P. (2020). Integration of VR with BIM to facilitate real-time creation of bill of quantities during the design phase: A proof of concept study. *Frontiers of Engineering Management*, *7*(3), 396–403. https://doi.org/10.1007/s42524-019-0039-y

Emmitt, S. (Ed.). (2013). Architectural technology research and practice. Wiley Blackwell.

EON Reality. (n.d.-a). *Application examples.* https://eonreality.com/application-examples/

EON Reality. (n.d.-b). *Augmented and virtual reality solutions*. https://eonreality.com/

EON Reality. (n.d.-c). *Your content, any reality*. DijiFyo.

EON Reality. (2020, September). *EON-XR desktop: User guide*. https://eonreality.com/wp-content/uploads/2020/09/EON-XR_Desktop_userGuide.pdf

G., R. (2021). *Open web steel joists—Dynamic component*. 3D Warehouse. https://3dwarehouse.sketchup.com/model/ada4fd3c-8aea-4e61-919d-9592bb1b888a/Open-Web-Steel-Joists-Dynamic-Component

Georgia Pacific Gypsum. (2021). *Floor ceiling steel-framed, 1 1/2 hour, UL G502*. 3D Warehouse. https://3dwarehouse.sketchup.com/model/u20dfef3d-12b5-43ee-b8ea-1d83e2f83814/Floor-Ceiling-Steel-Framed-1-12-Hour-UL-G502

Hasanzadeh, S., Polys, N. F., & de la Garza, J. M. (2020). Presence, mixed reality, and risk-taking behavior: A study in safety interventions. *IEEE Transactions on Visualization and Computer Graphics*, *26*(5), 2115–2125. https://doi.org/10.1109/TVCG.2020.2973055

Kubba, S. (2017). Handbook of green building design and construction: LEED, BREEAM, and Green Globes (2nd Ed.). Elsevier.

Lapointe, F. (2015). *Commercial/Industrial Building* [Architectural drawing]. Lapointe Architects.

Lejerskar, D. (2020, June 4). *Create virtual reality lessons immediately*. EON Reality. https://eonreality.com/create-immersive-lessons-for-online-learning/

Lewington, J. (2020, February 4). Augmented and virtual reality are helping colleges up their tech game. *Maclean's*. https://www.macleans.ca/education/college/augmented-virtual-reality-colleges-technology-learning/

Lu. Y. (2021a). *ARIF interim report #1* [Unpublished manuscript]. Department of Sustainable Design and Renewable Energy, Centennial College.

Lu. Y. (2021b). *ARIF interim report #2* [Unpublished manuscript]. Department of Sustainable Design and Renewable Energy, Centennial College.

Lu. Y. (2021c). *ARIF final report of phase 1* [Unpublished manuscript]. Department of Sustainable Design and Renewable Energy, Centennial College.

Martins, O. P., & Sampaio, A. Z. (2011). Bridge launching construction visualized in a virtual environment. *International Journal of Virtual Reality*, *10*(2), 49–56. https://doi.org/10.20870/IJVR.2011.10.2.2811

Page, N., & Millar, B. (2021, April 29). *The importance of construction drawings in every building design*. Greenway Hirst Page. https://ghp.biz/the-importance-of-construction-drawings-in-every-building-design/

Rahimian, F. P., Seyedzadeh, S., Oliver, S., Rodriguez, S., & Dawood, N. (2020). On-demand monitoring of construction projects through a game-like hybrid application of BIM and machine learning. *Automation in Construction*, *110*, Article 103012. https://doi.org/10.1016/j.autcon.2019.103012

Richardson, J. (2015, April 8). EON EON-XR, new virtual reality (VR) and augmented reality (AR) authoring software, empowers consumers to generate their own content. EON Reality. https://eonreality.com/eon-creator-avr-new-virtual-reality-vr-and-augmented-reality-ar-authoring-software-empowers-consumers-to-generate-their-own-content/

Sampaio, A. Z., & Viana, L. (2013). Virtual reality used as a learning technology: Visual simulation of the construction of a bridge deck. In *2013 8th Iberian Conference on Information Systems and Technologies (CISTI)* (pp. 1–5).

Soliman, M., Pesyridis, A., Dalaymani-Zad, D., Gronfula, M., & Kourmpetis, M. (2021). The application of virtual reality in engineering education. *Applied Sciences*, *11*(6), Article 6. https://doi.org/10.3390/app11062879

Trimble. (2017). *SketchUp* (Version 2017) [Computer software]. https://www.sketchup.com/page/homepage

University of Waterloo. (2021). *Understanding your learning style*. Centre for Teaching Excellence. https://uwaterloo.ca/centre-for-teaching-excellence/teaching-resources/teaching-tips/tips-students/self-knowledge/understanding-your-learning-style

VARK. (2021). *VARK modalities: What do visual, aural, read/write & kinesthetic really mean?* https://vark-learn.com/introduction-to-vark/the-vark-modalities/

Walshaw, E. (2021). *Technical drawing: Labelling and annotation*. First in Architecture. https://www.firstinarchitecture.co.uk/technical-drawing-labelling-and-annotation/

Wang, P., Wu, P., Wang, J., Chi, H.- L., & Wang, X. (2018). A critical review of the use of virtual reality in construction engineering education and training. *International Journal of Environmental Research and Public Health*, *15*(6), Article 1204. https://doi.org/10.3390/ijerph15061204

Waugh, B. (2017, January 19). *Will virtual reality become part of everyday life?* Vevox. https://www.vevox.com/blog/will-virtual-reality-become-part-of-everyday-life

Wienand, N. (2013). Theory and architectural technology. In S. Emmitt (Ed.), *Architectural Technology: Research & Practice* (1st ed., pp. 1-18). Wiley Blackwell.

Author

Yi Lu is pursuing a Doctor of Education at the Athabasca University, Alberta and is currently a contract faculty teaching in the architectural technician/technology program at Centennial College, Ontario. Yi is fascinated by the mixed reality experimented by the building industry and is intrigued to seek to adopt mixed reality in teaching practice. Email: yilu02@yahoo.ca

CJLT RCAT
Canadian Journal of Learning and Technology
La Revue canadienne de l'apprentissage et de la technologie

Volume 48 (4) Special Issue 2022

Removing Learning Barriers in Self-paced Online STEM Education

Supprimer les obstacles à l'apprentissage dans l'enseignement asynchrone en ligne des STIM

Hongxin Yan, *University of Eastern Finland, Finland*
Fuhua Lin, *Athabasca University, Canada*
Kinshuk, *University of North Texas, USA*

Abstract

Self-paced online learning provides great flexibility for learning, yet it brings some inherent learning barriers because of the nature of this educational paradigm. This review paper suggests some corresponding strategies to address these barriers in order to create a more supportive self-paced online learning environment. These strategies include a) increasing students' self-awareness of learning, b) identifying struggling students, and c) facilitating mastery learning. Focusing on Science, Technology, Engineering, and Mathematics (STEM) disciplines' delivery of self-paced online learning, this paper reviewed the role of formative assessment for learning. It is proposed that systematically designing and embedding adaptive practicing in STEM courses would be an effective learning design solution to implement these strategies. By examining the goals and context of adaptive practicing requested in this study, the feature requirements are depicted for such an adaptive practicing model. The models and techniques that can be used for adaptive assessment were then reviewed. Based on the review results, this paper argues that a reinforcement learning-based adaptive practicing model would be the best option to meet those feature requirements. Finally, we point out a research gap in this field and suggest a future research direction for ourselves and other researchers.

Keywords: Learning barrier; Adaptive practicing; Knowledge tracing; Exercise sequencing; Reinforcement learning; Self-paced online learning

Résumé

L'apprentissage en ligne asynchrone (à son propre rythme) offre une grande souplesse d'apprentissage, mais il comporte des obstacles à l'apprentissage inhérents à la nature de ce paradigme éducatif. Cet article de revue suggère quelques stratégies pertinentes permettant de répondre à ces obstacles afin de créer un environnement d'apprentissage en ligne asynchrone plus favorable. Ces stratégies comprennent a) l'augmentation de la conscience de l'apprentissage chez les étudiants, b) l'identification des étudiants en difficulté et c) la facilitation de la pédagogie de la maîtrise. En se concentrant sur la dispensation de l'apprentissage en ligne asynchrone dans les disciplines des sciences, de la technologie, de l'ingénierie et des mathématiques (STIM), cet article examine le rôle de l'évaluation formative pour l'apprentissage. Il est proposé que la conception et l'intégration systématiques de pratiques adaptatives dans les cours STIM constituerait une solution efficace de conception de l'apprentissage pour mettre en œuvre ces stratégies. En examinant les objectifs et le contexte de la pratique adaptative demandés dans cette étude, les exigences en matière de fonctionnalités sont décrites pour un tel modèle de pratique adaptative. Les modèles et les techniques qui peuvent être utilisés pour l'évaluation adaptative ont ensuite été examinés. Sur la base des résultats de cette revue, cet article soutient qu'un modèle de pratique adaptative basé sur l'apprentissage par renforcement serait la meilleure option pour répondre à ces exigences. Enfin, nous soulignons les insuffisances de la recherche dans ce domaine et suggérons une direction de recherche future pour nous-mêmes et pour d'autres chercheurs.

Mots clés : Barrière d'apprentissage ; pratique adaptative ; traçage des connaissances ; séquencement des exercices ; apprentissage par renforcement ; apprentissage en ligne asynchrone (à son rythme)

Introduction

Self-paced online learning (SPOL) has become an important educational model in higher education, where students can learn anytime, anywhere, and follow their own learning schedules. Such flexibility makes SPOL a vital self-directed educational paradigm, often adopted in adult learning, MOOCs, and life-long learning. In SPOL, students typically use asynchronous and independent learning approaches, often demanding high self-directed and self-regulated learning skills. However, because of the online distance and self-paced schedules, SPOL often lacks immediate feedback, communication, and collaboration among students and instructors. Thus, while enjoying the flexibility of SPOL, students could encounter some inherent learning barriers if the learning environment is not carefully designed.

From students' perspective, SPOL usually demands higher self-directed or self-regulated learning skills than synchronous or face-to-face educational paradigms. However, not every student has an adequate level of such skills (Kinshuk, 2016). For example, some students often wonder how well they have mastered the knowledge, where are their learning weaknesses, when they should ask for help, and if they are ready for the next topic or examination.

From instructors' perspective, because of limited communication with their students, the individualized learning pace and schedule impose a significant challenge for instructors to follow each student's learning progress. Thus, they usually have no clues whether a student is stuck somewhere in a topic unless students are reaching out to them for help. Hence, proactive academic intervention from instructors is often absent (Yan, 2020).

From the course design perspective, because of the limited feedback from students, it is not easy to learn about the effectiveness of the learning materials. Although course evaluation is usually embedded to get students' feedback about a course, its response rates are often relatively low in SPOL and may not pinpoint the design gaps.

These learning barriers often lead to students' struggle, poor performance, or even failure of a course. For example, according to a report from Athabasca University (Athabasca.ca, 2020), while most courses delivered at Athabasca University through SPOL have relatively high pass rates, some courses (including those in STEM disciplines – Science, Technology, Engineering, and Mathematics) still have pass rates as low as 50-60%. Therefore, to improve learning success, educators need to find solutions to remove these barriers in SPOL. Thus, this review paper will answer two main questions:

a) What strategies can be considered to alleviate these learning barriers?
b) What learning design solution has the potential to implement these strategies?

As different disciplines in different educational contexts need different learning approaches and pedagogies, this review paper focuses on Science, Technology, Engineering, and Mathematics (STEM) disciplines that are delivered through SPOL. STEM disciplines share certain common pedagogical needs, such as STEM-related conceptual development, scientific inquiry, engineering design, and problem-solving (Kennedy & Odell, 2014).

In this review paper, we first identified some strategies for alleviating the learning barriers in SPOL. Then, we proposed a possible solution from the learning design perspective – designing adaptive practicing in SPOL courses – to implement these strategies. Finally, we reviewed models and techniques that can be used for adaptive practicing and concluded with a suggestion for a reinforcement learning-based adaptive practicing model.

Some Strategies for Removing the Learning Barriers in SPOL

Educators have suggested many measures to improve learning success from different perspectives, such as providing more administration, technical, and advice support, increasing communication, motivation, and counselling service, or designing more engaging and effective instructional materials. In this review paper, we mainly investigated some strategies from the course design point of view with the goal of creating a more supportive SPOL learning environment. Focusing on the STEM disciplines and their pedagogical needs – conceptual development, scientific inquiry, and problem-solving, we recognize three critical strategies for removing learning barriers.

Increasing Learning Awareness to Improve Students' Self-directed Skills

Learning awareness means how much students know their learning progress and proficiency level with each knowledge component (KC). In this paper, KCs refer to cognitive units at different levels in a course, such as a concept, a skill, or a topic. With a better picture of their knowledge proficiency level (e.g., learning strengths and weaknesses), students can more effectively direct or regulate their learning, including seeking help and managing time. As pointed out by Pelánek (2017), students' meta-cognitive abilities, discussion with instructors, and self-regulated learning can be enhanced with increased awareness of their knowledge levels.

Identifying Academically Struggling Students to Enhance Proactive Intervention

Due to the difficulty of conceptual development and problem-solving (or steep learning curve), some students might encounter struggles during learning in a course. If alerted by the system for such struggling students, instructors can provide academic intervention proactively before those students become frustrated or give up. One type of struggle is wheel-spinning (or unproductive persistence). Wheel-spinning means students continuously make great efforts or invest considerable time in learning a concept or skill but without success (Beck & Gong, 2013). Wheel-spinning can be caused by a steep learning curve of a knowledge component, ineffective instructional materials, or students' low prior knowledge or learning approach. Owing to such students' desperation for success (or being highly motivated for learning), it is imperative for instructors to identify these wheel-spinning students and provide them with proactive academic intervention.

Facilitating Mastery Learning to Improve Success Rates

Given the need for conceptual and skill development in STEM disciplines, mastery learning should be promoted (Bloom, 1973; Guskey, 2010). For example, if students in a course are provided with practicing opportunities on knowledge components towards mastery learning, they can do much better to improve their performance. Otherwise, some students might barely meet the minimum requirements for passing a course if not failing it altogether. Thus, facilitating students' mastery of learning is crucial to improve pass rates and grades.

The Theoretical Background for Implementing these Strategies

To implement such strategies, we have examined what it entails for a practical solution by identifying the key learning process-related questions that need to be answered by the solution. First, we analyzed a typical learning process in SPOL.

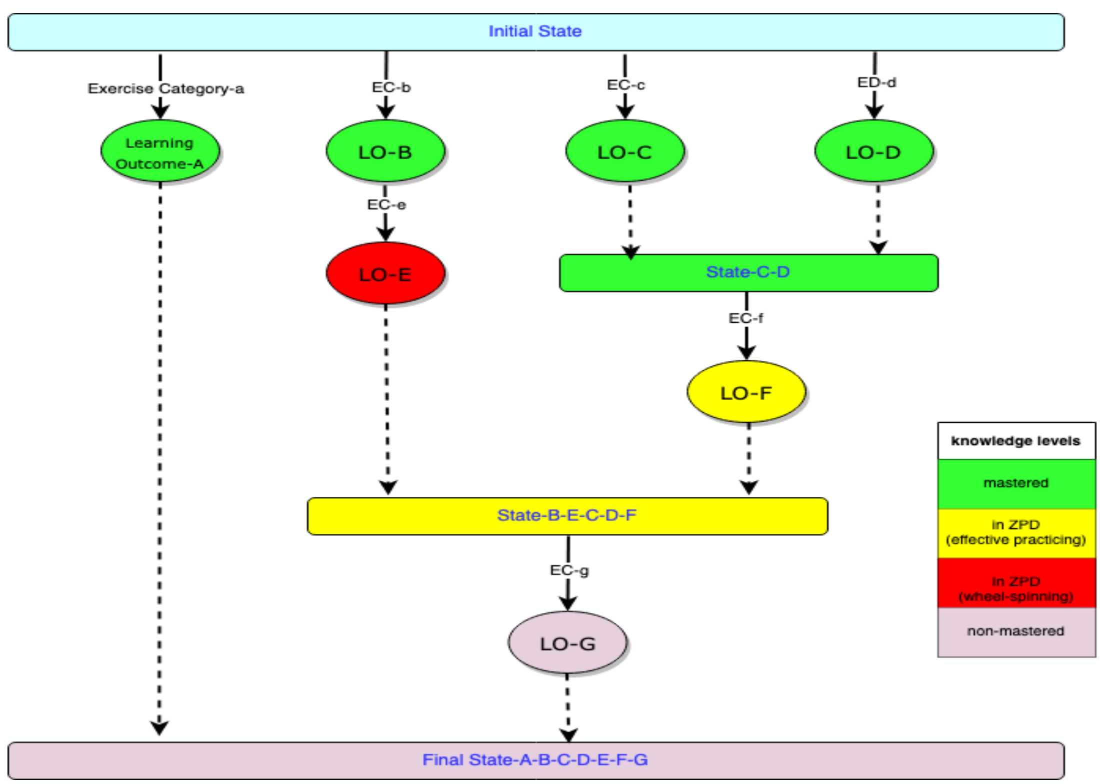
According to the knowledge space theory (Doignon & Falmagne, 1999), a field of knowledge is represented by a finite set of KCs. Each KC corresponds to some items (questions, problems, or tasks) for students to answer or solve. Prerequisite relationships usually exist among these knowledge components. A student's knowledge state is a subset of items that this student can solve. Possible knowledge states restricted by the prerequisite relationships among KCs form the knowledge space in a field or a course.

Like knowledge states, learning outcomes refer to the competencies students are expected to achieve after completing a topic or course. Revised Bloom's taxonomy is a widely used framework that defines learning outcomes in three major domains: the cognitive, the affective, and the psychomotor (Krathwohl, 2002). In the cognitive domain, learning outcomes are related to acquiring factual, conceptual, procedural, and meta-cognitive knowledge at six levels of cognitive processes. These six levels consist of three lower-order thinking skills (remember, understand, apply) and three higher-order thinking skills (analyze, evaluate, and create). Of them, the higher-order thinking skills learning usually depend on the mastery of the lower-order thinking skills (Krathwohl, 2002).

In SPOL, the learning outcomes usually drive course design and guide the learning process. Thus, this paper combines the knowledge space theory with revised Bloom's taxonomy to illustrate the typical learning process. In Figure 1, knowledge states is used to represent the sum of learning outcomes a student has achieved at a certain point during a topic or course learning. Because of the prerequisite relationships among knowledge components and the hierarchical relationships among the six levels of cognitive skills, learning outcomes and their corresponding exercise items (questions or tasks) are usually interdependent. As shown in Figure 1, some learning outcomes (LO) are independent (e.g., LO-A, B, C, and D), while others have prerequisite relationships (e.g., LO-E depends on LO-B, and LO-F depends on LO-C and LO-D). Also, exercise items are created to achieve each LO, possibly with different difficulty levels.

Figure 1

A Typical Learning Process



Note. Each node in this diagram stands for a learning outcome or knowledge state.

Based on the mastery learning theory and zone of proximal development (ZPD) theory (Vygotsky, 1997), this research categorizes the proficiency levels that a student achieves as mastered, ZPD (effective practicing), ZPD (wheel-spinning), and non-mastered. When students are in ZPD, learning happens if they are engaged with slightly challenging exercises while referring to hints, feedback, or remedial materials for each exercise item. In this situation, students are in the process of effectively learning and no human intervention is needed at this point. However, in some cases, students could be experiencing wheel-spinning when they are learning in ZPD. For example, as shown in Figure 1, the student is wheel-spinning at LO-E. Although the student has mastered the prerequisite knowledge components in LO-B, they cannot achieve LO-E even after practicing with all available exercise items in the EC-e category. Therefore, at that point, it should be the time for a human instructor to provide academic intervention.

Based on the above analysis, we expect that a practical solution should be able to answer the following questions in order to implement the strategies for removing those learning barriers in SPOL. As these questions are raised during the learning process, they are named Learning Process Questions (LP-Q) in this paper and for easier reference, including:

- LP-Q1: What proficiency level has a student reached at each learning outcome?
- LP-Q2: Which subsequent exercise should a student practice to gain maximum learning?
- LP-Q3: Is a student experiencing struggling or wheel-spinning and needing help?
- LP-Q4: Which parts of learning materials or activities are not effective?
- LP-Q5: How to sequence exercises so a student can reach the final mastery state with the minimum number of exercise items?

Possible Solutions

Formative Assessment

This paper proposes that systematically designing formative assessment in a SPOL course can answer the five LP-Q questions. As a low-stake evaluation approach, formative assessment is recognized as a fundamental process for learning (Menéndez et al., 2019). Formative assessment has great potential to enhance students' performance by providing knowledge estimation and learning feedback to students (Kingston & Nash, 2011). This statement indicates that formative assessment could answer the LP-Q1 (about detecting students' knowledge proficiency level). Different types of formative assessment can be embedded in online courses, such as self-testing, practicing, reflection, survey, etc. For STEM disciplines, two types of formative assessments are often used: self-diagnosis and self-practicing. Both types can help to learn by providing instructional feedback to students. Self-diagnosis usually provides a summary of feedback at the end of the assessment (e.g., pointing out all the learning weaknesses). In contrast, self-practicing provides learning hints, immediate and detailed feedback, and remediation along with each item or step (e.g., why the answer is wrong). Thus, self-diagnosis is mainly used to estimate a student's knowledge proficiency, while self-practicing is to improve a student's knowledge proficiency level during the assessment. Which type of formative assessment is used depends on the purpose, design conditions, and context. For example, self-diagnosis can be used for pre-tests at the beginning of the course, while self-practicing can be used for learning a topic or preparing for an examination.

Potential of Adaptive Practicing

Currently, the one-size-fits-all formative assessment is often adopted due to its easy implementation. It delivers a set of pre-determined items to all students. However, because of the differences in background knowledge, a student might consider some questions too easy while another might feel them too difficult. Therefore, with the fixed question items, time could be wasted, and students could get bored or frustrated. To address this problem, adaptive assessment can be adopted.

The adaptive formative assessment uses specific intelligence techniques to tailor assessment items to individual students' knowledge or skill level by choosing a subsequent item based on a student's responses to previous items (Weiss & Kingsbury, 1984). Therefore, the most crucial feature of adaptive assessment is to detect a student's knowledge level, especially the learning weakness (Yan, 2020). By this, the adaptive assessment should answer the question LP-Q1 (about detecting students' knowledge proficiency level). Suppose an adaptive assessment mechanism is used in self-diagnosis. In that case, it can choose items with high discrimination values for individual students, thus, reducing the assessment time or improving the accuracy of knowledge estimation with the same number of items (Sorrel et al., 2020). If an adaptive assessment mechanism is used in self-practicing (we call it adaptive practicing in this review paper), adaptive practicing should not only estimate a student's knowledge level efficiently but also trigger more exercises that target a student's weaknesses (Yan et al., 2021). Thus, adaptive practicing can promote mastery learning more effectively (Beck & Gong, 2013) if the adaptive instructional policy is based on the principles of mastery learning (Pelánek, 2017). Therefore, adaptive practicing could also answer LP-Q1 (about detecting students' knowledge proficiency level). In addition, adaptive practicing has the potential to answer LP-Q2 (about selecting the next effective exercise) and LP-Q5 (about sequencing exercises for mastery learning) if appropriately designed.

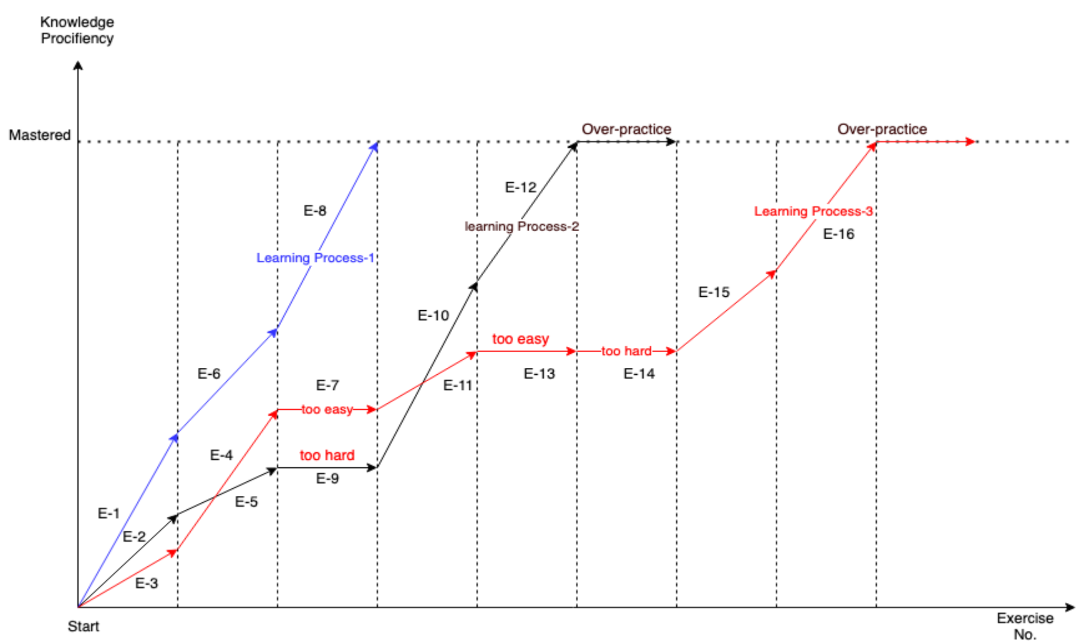
During the mastery learning process with adaptive practicing, it is also possible to detect wheel-spinning. Insights obtained from knowledge tracing can help identify students who need specific treatment or intervention (Pelánek, 2017). For example, if the system notices that a student has worked on the maximum number of exercises for a learning outcome but still cannot succeed, it most likely means that the student is wheel-spinning and needs help. Therefore, the adaptive practicing should be able to answer LP-Q3 (about identifying struggling students).

Wheel-spinning can be caused by individual students' factors (such as low prior knowledge or limited learning ability) or by design factors (such as the steep learning curve of a knowledge component or ineffective instructional materials). This paper assumes that if wheel-spinning happens to only a few individuals who are learning a knowledge component, it is most likely due to student factors. But if wheel-spinning occurs to most students with the same knowledge component, it is probably due to ineffective instructional materials or other design factors. As suggested by Pelánek (2017), the knowledge tracing function embedded in assessment can help to identify problematic items, learning materials, or knowledge structure. Therefore, adaptive practicing with knowledge tracing function can answer LP-Q4 (about detecting ineffective learning materials).

To promote mastery learning, there has been an emerging interest in applying certain techniques in adaptive learning to sequence learning content or tasks. For example, He-Yueya and Singla (2021) used reinforcement learning to sequence quiz questions. If such sequential decision-making technologies are adopted in adaptive practicing, LP-Q5 (about sequencing exercises for mastery learning) can be answered. Figure 2 illustrates that different exercise sequences have different effects on the learning process in terms of practicing effectiveness. When learning a concept or a skill, practicing can be an effective approach. But different exercise sequences could end up with different learning processes (e.g., LP-1, 2, and 3 in Figure 2). If an exercise selected is too easy or too hard for the student, time would be wasted, and the student could feel bored or frustrated (e.g., LP-3). Therefore, the adaptive practicing model should be able to select exercises that can effectively facilitate mastery learning. In other words, selecting an exercise sequence that consists of the minimum number of exercises to reach mastery of learning is the primary goal of an adaptive practicing model.

Figure 2

Exercise Question Sequencing Optimization



Note. Different exercise selections and sequences affect mastery learning process

Therefore, embedding adaptive practicing in courses can accurately estimate students' knowledge states (to answer LP-Q1), select the effective subsequent exercise (to answer LP-Q2), help detect wheel-spinning students (to answer LP-Q3), identify ineffective instructional materials (to answer LP-Q4), and promote mastery learning with the minimum number of exercises (to answer LP-Q5). Given its potential, we argue that systematically designing and embedding adaptive practicing in courses can be a possible solution for removing learning barriers in self-paced STEM courses.

Feature Requirements for the Adaptive Practicing Model

To meet the above functional needs, this literature review identifies some key features that an adaptive practicing model should provide:

Knowledge Tracing

This model should quickly estimate a student's proficiency level or trace the knowledge level based on a student's responses to previous exercise items. However, since adaptive practicing is a low-stake evaluation, its demand on the accuracy of knowledge tracing is not as strict as for high-stake summative assessment. Also, the primary goal of adaptive practicing is to gain learning while checking hints, feedback, and remediation recommendation. Thus, students' knowledge and skill levels will change during the practice process. Therefore, first and foremost, tracing the changing knowledge level should be the fundamental function of this adaptive practicing model.

Mastery Learning Promotion

To promote mastery learning, the adaptive practicing model should provide students with exercise items that are slightly challenging, meaning the model should always choose the next exercise that is in a student's ZPD of a KC until the KC is mastered. In the meantime, criteria for detecting wheel-spinning should be built into this model.

Exercise Sequencing

According to the knowledge space theory and Bloom's cognitive process framework, prerequisite relationships among learning outcomes in a course or topic usually exist. Also, because contents are interrelated, a student's knowledge state may be a complicated function of the history of activities done so far for different KCs (in this case, the exercises completed so far) (Doroudi et al., 2019). Therefore, this model should be able to cope with such a complex and uncertain practicing environment to determine the most effective exercise sequence.

Online Machine Learning Approach

Students in the SPOL follow different learning paces and learning approaches. In addition, due to students' different prior knowledge and learning ability, applying a pre-trained model to a new student is often inappropriate. Therefore, an online machine learning approach should be considered, where data in a sequential order is used to update the prediction as opposed to using an entire training data set at once.

To find an appropriate adaptive practicing model that can provide the above features, this paper has reviewed the models and techniques developed for adaptive assessment, as described in the following section.

A Review of Models and Techniques Used for Adaptive Assessment

Among the adaptive assessment models and techniques developed so far, some focus on knowledge diagnosis, and others focus on learning promotion. In either case, knowledge tracing is an essential function of adaptive assessment.

As pointed out by Liu et al. (2021),

> Given the sequence of students' learning interactions in online learning systems, knowledge tracing aims to monitor students' changing knowledge states during the learning process and accurately predict their performance on future exercises; this information can be further applied to individualize students' learning schemes in order to maximize their learning efficiency. (p.3)

The majority of knowledge tracing models can be grouped into several categories, including logistic models, probability models, deep learning-based models, cognitive diagnosis models, and reinforcement learning-based models.

Logistic Models

Based on the logistic function, these models use a mathematical function of student parameters and KC parameters to represent the probability of correctly answering the next question. For example, item response theory model (Hambleton et al., 1991) and performance factor analysis (Pavlik Jr et al., 2009) were developed in the context of computerized adaptive testing. However, since such models are typically based on the assumption that a student's knowledge level is constant, this contradicts the knowledge changing during practicing. Therefore, these models can hardly be used for adaptive practicing.

One exception to the logistic models is the Elo rating system (Elo, 1978), which tracks changing knowledge during the assessment. It can accommodate guessing behaviour, individual item difficulty, measuring correlated skills, and partial credit modelling of answers in the presence of hints, response time, etc. However, the Elo rating system is mainly applied in domains with simple structures (such as declarative knowledge, vocabulary learning, and simple procedure knowledge). Moreover, it needs enough historical data to fit the parameters first (Pelánek, 2017). Therefore, the Elo rating model does not meet the complex needs of the STEM disciplines and the context of SPOL in this study.

Probability Models

Probability models treat the learning process as a Markov process, where students' latent knowledge state can be estimated by their observed learning performance (assessment results) (Corbett & Anderson, 1995). The classic and widely used model in this category is Bayesian knowledge tracing (BKT) (Corbett & Anderson, 1995), which uses the Bayesian networks technique and assumes that the learning process is a two-state (learned or unlearned) hidden Markov model (HMM). This model uses four interpretable parameters to estimate a student's knowledge state, including the initial learning probability (L_0), learning transition probability (T), guessing probability (G), and slipping probability (S). Although BKT can be used to trace knowledge change, it requires a large amount of prior student data. Additionally, the standard BKT model assumes that KCs are independent of each other, and one set of parameters is for one KC only. Some extended BKT models, including dynamic Bayesian knowledge tracing (Kaser et al., 2017), can model the prerequisite hierarchies and relationships within KCs. But all BKT models would use historical data to train a model first and usually do not consider the difference between students (e.g., learning ability and prior knowledge). Thus, such models can barely meet the feature requirements of the adaptive practicing model.

Deep Learning-based Models

In recent years, research on deep learning-based knowledge tracing models shows its powerful ability to deal with the complex learning process and has achieved quite good performance. One typical example is deep knowledge tracing (DKT) (Piech et al., 2015), which utilizes recurrent neural networks or long short-term memory networks to provide a high-dimensional and continuous representation of students' knowledge states. Some variants of DTK can handle the relationship among KCs and other side information. However, deep learning-based models are poorly interpretable due to their end-to-end learning characteristics. This limits their applicability due to the crucial significance of interpretability in education. Like BKT, DKT also needs considerable training data to fit the model first. Moreover, although DKT can be used to schedule exercises, it cannot be used to optimize the efficacy of exercises (Bassen et al., 2020). Therefore, the deep-learning models are mainly developed to estimate knowledge level rather than promote mastery learning. So, DKT models are not appropriate for adaptive practicing.

Cognitive Diagnostic Models

Cognitive diagnostic models (CDMs) have been developed to detect mastery and non-mastery of knowledge or skills based on a Q-matrix (a map of the relationship between assessment items and the skills) (de la Torre, 2009). Compared to the unidimensional item response models, CDMs can provide a more detailed evaluation or more granular evidence of the strengths and weaknesses of students. As such, these models focus on task mastery and guide how students invest efforts in competency rather than grade achievement (Shepard et al., 2018). CDMs include a broad family of models, such as DINA, DINO, and GenMa. However, all these models require large data samples to estimate skills effectively. Although CDMs can provide more detailed insights into a student's knowledge state (e.g., where the learning gaps are), they lack the ability to sequence exercises to maximize learning. Therefore, it would be hard to use CDMs in adaptive practicing.

Reinforcement Learning-based Models

Reinforcement learning (RL) is a computational framework for modelling and automating goal-directed learning and sequential decision-making (Sutton & Barto, 2018). Given the centrality of sequencing learning content or tasks, there has been an emerging interest in applying RL to improve students' performance. For example, He-Yueya and Singla (2021) investigated how an RL-based policy can be used for quizzing students to infer their knowledge state. Bassen et al. (2020) developed a reinforcement scheduling model to maximize learning gains while reducing the time spent on educational activities. As one RL family, multi-armed bandit algorithms (Berry & Fristedt, 1985) are also starting to attract researchers' attention in the educational world (Lin, 2020). For example, Clement et al. (2015) used multi-armed bandits in an intelligent tutoring system. Therefore, RL-based models hold great potential for adaptive practicing.

Towards Reinforcement Learning-based Adaptive Practicing Design

After examining these adaptive assessment models, we believe most models can be used for adaptive self-diagnosis, which aims to detect a student's static knowledge proficiency level. However, for adaptive practicing, we argue that RL-based models would be the best option that can potentially meet all the feature requirements identified in this paper. Reinforcement learning uses a rewarding mechanism to sequence actions to optimize the outcomes in an uncertain and changing environment without pre-populating a model with historical data (Kaelbling et al., 1996).

First, the adaptive practicing system in this study is researched in an uncertain and changing environment. The prerequisite and interdependent relationships among KCs make learning a complicated function of previous practicing history. For example, completing exercises successfully for a particular KC could mean that a student has mastered the current KC and its prerequisite KCs. Additionally, a student's knowledge state across many KCs could constantly change while simultaneously completing every exercise item. However, because of students' different learning approaches and prior knowledge, the number of exercises and which exercises a student needs variety in mastering a KC. Compared to other types of models, RL-based models can better handle such uncertain and changing environments better than other models.

Secondly, because of students' different learning backgrounds and learning paces in SPOL, a pre-trained model would hardly work for adaptive practicing in such an educational paradigm. Reinforcement learning is an online machine learning technology that does not need historical data to fit a model first. Unlike other models that typically require historical student data and model training, a RL-based model can make decisions and learn from their outcomes continuously and in real time (Bassen et al., 2020).

Finally, RL aims to use a rewarding mechanism to sequence actions and optimize the outcomes. In our case, RL-based models can be used to sequence exercises to promote mastery learning with the minimum number of exercises. Sequential decision-making is an essential advantage of RL-based models over other types of models when they are used for adaptive practicing.

We argue that the reinforcement learning-based model is the best candidate for adaptive practicing. As designed by Bassen et al. (2020) for reinforcement scheduling, which adaptively selects assignment that leverages reinforcement learning and requires no pre-existing course data or skill labels, we can design an RL model-based adaptive practicing system.

A Typical Use Case Scenario of Adaptive Practicing

Adaptive practicing can be embedded in a course for mastering a topic, preparing for examinations, or passing the whole course. A typical use of adaptive practicing would be preparing students for the mid-term or the final examination. As a high-stakes assessment, the examination evaluates a student's knowledge proficiency and motivates students to review and synthesize what they have learned in the previous topics. However, if a student gets poor performance on such a high-stakes assessment, it could result in a lower grade or even failing a course. Therefore, it would be necessary for students to get ready for the examination. This is where adaptive practicing can play a role.

Since examination usually spans multiple learning topics with many KCs, it would be ideal for students to know which parts still need more effort and how to invest their time in different KCs prior to taking the exam. Thus, it is by adaptive practicing that students can not only efficiently identify their learning weaknesses or gaps but also effectively fill such learning gaps. Furthermore, with the alert function of adaptive practicing, a student can self-determine if they are experiencing wheel-spinning.

Conclusion

This review paper identified the inherent learning barriers in self-paced online learning, such as the high demand for self-directed learning skills, low learning awareness, lack of proactive academic support, lack of students' feedback, and poor academic performance. Focusing on STEM disciplines delivered in SPOL, we suggest three essential strategies for alleviating those barriers – increasing students' self-awareness of learning, identifying struggling or wheel-spinning students, and facilitating mastery learning. We argue that systematically designing adaptive practicing in STEM courses could be an effective solution for implementing these strategies. Then, this paper depicts a typical SPOL learning process according to knowledge space theory and Bloom's taxonomy of learning. From there, a few key questions to be answered by the adaptive practicing system are determined. Based on these questions, the features requested for the adaptive practicing model are identified. After reviewing the models and techniques used for adaptive assessment, we argue that a reinforcement learning-based model would be the best option for adaptive practicing. We hope that this preliminary review work can help educators to understand the challenges of SPOL and the potential of adaptive practicing design in addressing these challenges in STEM disciplines.

Future Work

At this point, we have advocated several strategies for addressing the learning barriers in SPOL through adaptive practicing, which we argue is a promising and partial solution. However, using a reinforcement learning model for adaptive practicing still needs more research. As Clement et al. (2015) pointed out, most RL models only consider the correct or incorrect answer for knowledge tracing. Additionally, other aspects of information could be valuable, such as response time, clue click, learner feedback, etc. This is especially true in the case of adaptive practicing because answer correctness alone does not usually tell if an exercise is effective or within a student's ZPD.

Based on the potential of the RL-based model for adaptive practicing and the research gap, we outline some future work and the methodology for further research, mainly for our study, including (1) stage-1: designing an RL-based adaptive practicing model, which will embed an algorithm that considers not only the answer correctness but also some vital side information; (2) stage-2: creating a prototype adaptive practicing system and simulating the model; (3) stage-3: conducting a comparison experiment with some real-world courses; and (4) stage-4: validating our hypothesis about the effectiveness of the solution and model through learning data and a survey.

References

Athabasca.ca. (2020). *About AU - Accreditation*. (Athabasca University Student Consumer Info). https://www.athabascau.ca/aboutau/accreditation/student-consumer-info.html

Bassen, J., Balaji, B., Schaarschmidt, M., Thille, C., Painter, J., Zimmaro, D., Games, A., Fast, E., & Mitchell, J. C. (2020). Reinforcement learning for the adaptive scheduling of educational activities. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–12. https://doi.org/10.1145/3313831.3376518

Beck, J. E., & Gong, Y. (2013). Wheel-spinning: Students who fail to master a skill. *International Conference On Artificial Intelligence In Education* (pp. 431-440). Springer. https://doi.org/10.1007/978-3-642-39112-5_44

Berry, D. A., & Fristedt, B. (1985). *Bandit problems: Sequential allocation of experiments (Monographs on statistics and applied probability)* (Vol. 5). Chapman and Hall. https://doi.org/10.1007/978-94-015-3711-7

Bloom, B. S. (1973). Recent developments in mastery learning. *Educational Psychologist*, *10*(2), 53–57. https://doi.org/10.1080/00461527309529091

Clement, B., Roy, D., Oudeyer, P.-Y., & Lopes, M. (2015). Multi-armed bandits for intelligent tutoring systems. *Journal of Educational Data Mining*, *7*(2), 20–48. https://doi.org/10.48550/arXiv.1310.3174

Corbett, A. T., & Anderson, J. R. (1995). Knowledge tracing: Modeling the acquisition of procedural knowledge. *User Modeling and User-Adapted Interaction, 4*(4), 253–278. https://doi.org/10.1007/BF01099821

de la Torre, J. (2009). DINA model and parameter estimation: A didactic. *Journal Of Educational And Behavioral Statistics, 34*(1), 115-130. https://doi.org/10.3102/1076998607309474

Doignon, J.-P., & Falmagne, J.-C. (1999). *Knowledge spaces.* Springer-Verlag.

Doroudi, S., Aleven, V., & Brunskill, E. (2019). Where’s the reward? *International Journal of Artificial Intelligence in Education, 29*(4), 568-620. https://doi.org/10.1007/s40593-019-00187-x

Elo, A. (1978). *The rating of chessplayer. past and present*. Arco.

Guskey, T. (2010). Lessons of mastery learning. *Educational Leadership, 68*(2), 52-57. https://uknowledge.uky.edu/edp_facpub/14

Hambleton, R. K., Swaminathan, H., & Rogers, H. J. (1991). *Fundamentals of item response theory.* Sage Press.

He-Yueya, J., & Singla, A. (2021). Quizzing policy using reinforcement learning for inferring the student knowledge state. *Proceedings of The 14th International Conference on Educational Data Mining (EDM 2021)*. https://files.eric.ed.gov/fulltext/ED615585.pdf

Kaelbling, L. P., Littman, M. L., & Moore, A. W. (1996). Reinforcement learning: A survey. *Journal of Artificial Intelligence Research. 4*, 237–285. https://doi.org/10.1613/jair.301

Kaser, T., Klingler, S., Schwing, A., & Gross, M. (2017). Dynamic bayesian networks for student modeling. *IEEE Transactions on Learning Technologies, 10*(4), 450–462. https://doi.org/10.1109/TLT.2017.2689017

Kennedy, T. J., & Odell, M. R. (2014). Engaging students in STEM education. *Science Education International, 25*(3), 246-258. https://files.eric.ed.gov/fulltext/EJ1044508.pdf

Kingston, N., & Nash, B. (2011). Formative assessment: A meta-analysis and a call for research. *Educational measurement: Issues and practice, 30*(4), 28-37. https://doi.org/10.1111/j.1745-3992.2011.00220.x

Kinshuk. (2016). *Designing adaptive and personalized learning environments*. Routledge.

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into practice, 41*(4), 212-218. https://doi.org/10.1207/s15430421tip4104_2

Lin, F. (2020). Adaptive quiz generation using Thompson sampling. *Third Workshop Eliciting Adaptive Sequences for Learning (WASL 2020), co-located with AIED 2020.* https://jiji.cat/wasl2020/adaptive-quiz-generation.pdf

Liu, Q., Shen, S., Huang, Z., Chen, E., & Zheng, Y. (2021). A survey of knowledge tracing. *ArXiv Preprint ArXiv:2105.15106*. https://doi.org/10.48550/arXiv.2105.15106

Menéndez, I. Y., Napa, M. A., Moreira, M. L., & Zambrano, G. G. (2019). The importance of formative assessment in the learning teaching process. *International Journal Of Social Sciences And Humanities, 3*(2), 238-249. https://doi.org/10.29332/ijssh.v3n2.322

Pavlik Jr, P. I., Cen, H., & Koedinger, K. R. (2009). Performance Factors Analysis—A New Alternative to Knowledge Tracing. *Online Submission*. https://doi.org/10.1007/s11257-017-9193-2

Pelánek, R. (2017). Bayesian knowledge tracing, logistic models, and beyond: An overview of learner modeling techniques. *User Modeling and User-Adapted Interaction, 27*(3), 313-350. https://doi.org/10.1007/s11257-017-9193-2

Piech, C., Spencer, J., Huang, J., Ganguli, S., Sahami, M., Guibas, L., & Sohl-Dickstein, J. (2015). Deep knowledge tracing. *arXiv Preprint ArXiv:1506.05908*. https://proceedings.neurips.cc/paper/2015/file/bac9162b47c56fc8a4d2a519803d51b3-Paper.pdf

Shepard, L. A., Penuel, W. R., & Pellegrino, J. W. (2018). Using learning and motivation theories to coherently link formative assessment, grading practices, and large-scale assessment. *Educational Measurement: Issues and Practice, 37*(1), 21-34. https://doi.org/10.1111/emip.12189

Sorrel, M., Barrada, J. R., de la Torre, J., & Abad, F. (2020). Adapting cognitive diagnosis computerized adaptive testing item selection rules to traditional item response theory. *PLoS ONE, 15*(1). https://doi.org/10.1371/journal.pone.0227196

Sutton, R. S., & Barto, A. G. (2018). *Reinforcement Learning: An Introduction.* MIT Press.

Vygotsky, L. S. (1997). The historical meaning of the crisis in psychology: A methodological investigation. *Problems of the Theory and History of Psychology, 3*, pp. 233-344.

Weiss, D. J., & Kingsbury, G. G. (1984). Application of computerized adaptive testing to educational problems. *Journal of Educational Measurement, 21*(4), 361–375. https://doi.org/10.1111/j.1745-3984.1984.tb01040.x

Yan, H. (2020). Using learning analytics and adaptive formative assessment to support at-risk students in self-paced online learning. *In 2020 IEEE 20th International Conference on Advanced Learning Technologies (ICALT),* 396-398. https://doi.org/10.1109/ICALT49669.2020.00125

Yan, H., Ives, C., & Lin, F. (2021). Adaptive practicing design for self-paced online learning. *Proceedings of the 29th International Conference on Computers in Education,* 765-768. https://icce2021.apsce.net/wp-content/uploads/2021/12/ICCE2021-Vol.II-PP.-765-768.pdf

Authors

Hongxin Yan is a doctoral student at the School of Computing, University of Eastern Finland, Finland and works as a Learning Designer in the Faculty of Science and Technology, Athabasca University, Canada. His research interests include personalized and adaptive learning in online education. Email: hongya@student.uef.fi. https://orcid.org/0000-0002-3729-0844

Dr. Fuhua Lin is Professor and former Chair for the School of Computing and Information Systems, Faculty of Science and Technology, Athabasca University, Canada. He is the Coordinator of Intelligent Systems and Machine Learning research cluster of Athabasca University and a senior member of IEEE and ACM.

Dr. Kinshuk is Dean of the College of Information, University of North Texas, USA. Previously Kinshuk was the NSERC/CNRL/Xerox/McGraw Hill Research Chair for Adaptivity and Personalization in Informatics, and Professor and Associate Dean in the Faculty of Science and Technology, Athabasca University, Canada. http://www.kinshuk.info/ Email: kinshuk@unt.edu