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The field of education technology, and related subject areas attendant to it, welcomed millions of new participants during the COVID-19 pandemic. According to UNESCO, the education experiences of more than 1.4 billion students were disrupted in ways that will impact them, and those around them, for years to come. This journal has a significant role to play for documenting these experiences and the research that followed. Evidence about the use of learning technologies for learning in many new education spaces and geographic places is now available. Interest in the topic of technology-enabled learning has increased exponentially and submissions documenting these new experiences, insights, research findings, and practice applications have continued to grow. Our journal supports scholars long involved in, or new to the topic of, technology-enabled learning design and delivery.

In this issue's Notes Section, we are privileged to present this invited publication written by **Dr. Sarah Eaton**, faculty member at the University of Calgary: ***The Academic Integrity Technological Arms Race and its Impact on Learning, Teaching, and Assessment*.** For Dr. Eaton, well-known for her expertise on academic integrity, a technological arms race has developed in response to academic cheating. The three technological advances that impact academic integrity are identified and assessed: a) text-matching software, b) online exam proctoring software, and c) artificial intelligence and Large Language Models (LLMs). I know you will find value in Dr. Eaton's suggestion that there is no "silver bullet" for preventing or investigating academic misconduct. Instead, she submits, our ethical obligations for learning, teaching, and assessment must include a human focus and promotion of student success.

Research-based articles in this issue focus on technology usage, teaching, and learning. Article one, titled ***Using Technology for Learning: Generalizable Lessons from on Educational Technology Integration in Kenya*,** is presented by **Adeela Arshad-Ayaz** and **M. Ayaz Naseem** of Concordia University, Montreal, Canada and **Justus O. Inyega** from the University of Nairobi, Kenya. All important lessons learned on the integration of technology in the Kenyan education system from a multi-year partnership project are revealed. As recently suggested by UNESCO, global partnerships are the key to creating a new social contract between education and society. Also important is the academic rigor required to assess such activities. In this paper, research using methodological strategies on the intersections of critical discourse analysis and critical ethnography describes the integration of technology in this Kenyan case. Included are examples and evidence about the pedagogical and societal successes and challenges during technology integration. In support of the need for change, lessons from qualitative findings are presented.

Article two presents results that emerged from using inquiry-based pedagogical practices. ***Student-Generated Questions Fostering Sustainable and Productive Knowledge Building Discourse*** is written by **Gaoxia Zhu**, **Ahmad Khanlari**, and **Monica Resendes** of the University of Toronto in Canada. These scholars examined student-generated questions in the process of Knowledge Building discourse. The role of questions in student learning is a common but controversial issue: who is best responsible for question posing and topic? For some, teachers should generate questions to ensure the questions are of high-quality. Others emphasize student agency and the need for relevant questions. Comparing question threads, findings indicate that questions posted by students generated sustainable and progressive discourses. Content analysis also revealed that the threads starting with questions were more likely to end up with productive threads than the non-question threads.

What factors, beyond access to technology, impact equitable use of computers in schools? **Fernando Fraga-Varela** of University of Santiago de Compostela and **Almudena Alonso-Ferreiro** from the University of Vigo in Spain provide case study data in article three, ***Digital Competence in Primary Education and the Limits of 1:1 Computing*.** What are the effects of technology on the lives of children in situations of socio-cultural and economic exclusion? Findings from three case studies, using ethnographic in-depth interviews and participant observation, are presented. Data suggest that family context and digital competence is heavily dependent on the opportunities provided at school. However, where advanced learning experiences with information and communication technology are not provided at school, school policies are needed to address this gap. Those leading the transformation through education ***with*** digital technology and education ***about*** digital technology will find this consideration valuable.

Beyond one's context, individual differences also impact the quality of virtual education experiences. In article four, ***University Learners' Motivation and Experiences in Using Virtual Laboratories in a Physics Course*** are examined by **Gülgün Afacan Adanır** at Ankara University, Turkey with **Azat Akmatbekova** and **Gulshat Muhametjanova** of Kyrgyz-Turkish Manas University, Kyrgyzstan. This study measured learners' use of virtual laboratories in a university-level physics course. Over three-hundred undergraduate students participated in one of three groups: two different virtual laboratory platforms or a face-to-face lab. Quantitative data results demonstrated differences across groups concerning individual motivation and experience. In addition, learners' physics laboratory attitudes differed across gender and grade point average (GPA).

Where is the balance point between the technology supporting digitalization and the theory supporting pedagogicalization? For **Jeremy Dennis** of St. Louis Community College, USA, advancements in technology continue to outpace the Scholarship of Teaching and Learning (SoTL) with technology. In a more macro-level discussion of the need for high education change, ***(Re)Framing Our Frames: Architectonics, Intertextuality, and the Scholarship of Integration in Online Education*** calls for a reconsideration of Ernest Boyer's ideas. Boyer suggested a need for the appreciation of integration as convergence or *intertextuality* in combination with its digital correlate or *hypertextuality* to operationalize online education. With the addition of disciplinarity to this yet unachieved convergence, Dennis' meta-synthesis offers Peircean architectonics as the paradigm that reframes our understanding of convergence and illuminates its actualization of online education theory. This provides online educators with a common discourse and interdisciplinary framework that will advance the scholarship of integration in online education.

The Canadian Journal of Learning and Technology publishes articles in English and French that illuminate the role, the scope, and the complexity of technology-enabled learning in theory and practice. The COVID-19 pandemic caused vast amounts of experience with technology-enabled learning as a process of safe distancing, an amount of experience that could not have been predicted or generated in any other way. This reality has renewed our commitment to reporting research on technology that bridges required distances, adds quality, and offers ideas about new ways of doing the business of education. We are in this together. Wherever you are, geographically and educationally, we wish you well in the continued research and development of techno-pedagogical forms for education.

We take this opportunity to thank Dr. Sawsen Lakhal, CJLT's Éditrice en Français of the last three years, for her dedication and commitment to bilingual dissemination of results in our journal. Dr. Lakhal is stepping away to address other critical projects in her education scholarship. As a result, we are in search of another bilingual education scholar willing to adopt this role. If interested, please contact CJLT's Managing Editor Ms. Carmen Jensen-Tebb at cjlt@ualberta.ca, or me at martic@athabascau.ca.

Please share your views about and suggestions for CJLT with us. We look forward to receiving future submissions from you as education researchers and practitioners of all types from all places in the world.

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The Academic Integrity Technological Arms Race and its Impact on Learning, Teaching, and Assessment

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Abstract

This essay discusses the technological arms race that has developed in response to academic cheating. The author highlights three technological advances that impact academic integrity, from oldest to newest: a) text-matching software, b) online exam proctoring software, and c) artificial intelligence and Large Language Models (LLMs). This essay argues that there is no "silver bullet" to preventing or investigating academic misconduct and that our ethical obligations for learning, teaching, and assessment must include a human focus to promote student success.

Keywords: Academic integrity; Academic misconduct; Technology; Text-matching software; Artificial intelligence; Online proctoring

Introduction

Academic cheating can be traced back to the sixth century when exams were first used on a large scale in China (Lang, 2013). Plagiarism began to emerge as a topic of concern in writing with the advent of the printing press in the fifteenth century (Eaton, 2021). The commercialization of the Internet provided an opportunity for traditional term paper mills to move online, creating a global industry for academic outsourcing, which is today known as 'contract cheating' (Clarke & Lancaster, 2006). Large-scale changes in technology and advances in education bring new ways for students to engage in learning – and academic misconduct.

In this article, I discuss some major advances in technology that have impacted education and academic integrity and point to topics that educators, administrators, and policy makers may need to pay more attention to in the coming years. The main argument I present is that the technological "arms race" (Mortati & Carmel, 2021; Thomas & Scott, 2016) does little to support students or to promote ethical approaches to teaching and learning. For decades, scholars have argued against a "Gotcha!" approach that focuses on catching student cheaters, instead advocating vehemently that we must prioritize student learning above catching cheaters

(Bertram Gallant, 2008; Howard, 2001; Morris, 2016). Academic misconduct is a complex and nuanced aspect of higher education that cannot be solved by technology; however, there are technologies that can help educators promote integrity and address its breaches, but humans are always part of the solution.

In the sections that follow I highlight three technological advances in the field of academic integrity, from oldest to newest: a) text-matching software, b) online exam proctoring software, and c) Artificial Intelligence and Large Language Models (LLMs). The first two are often used to prevent or detect cheating, whereas the third might result in students being found responsible for misconduct, possibly without cause. I argue that there is no "silver bullet" to preventing, investigating, or solving academic misconduct and that our ethical obligations for learning, teaching, and assessment must include a human focus to promote student success.

Text-Matching Software

Commonly known commercial text-matching software (TMS) products include Turnitin and iThenticate. This type of software is erroneously referred to as "plagiarism-detection software" or "anti-plagiarism software" because such technology cannot detect plagiarism *per se* (Bretag & Mahmud, 2009; Hayden et al., 2021; Weber-Wulff, 2016). Instead, TMS identifies exact textual matches between documents and produces a report that highlights textual matches or similarities for further analysis. The decision about whether such a match constitutes plagiarism must be determined by a human, preferably one who is trained and experienced using the software (Bretag & Mahmud, 2009; Hayden et al., 2021; Weber-Wulff, 2016).

An analogy (though an imperfect one) to help readers understand this subtle but important difference would be a comparison to radiology. An X-ray can reveal anomalies, but it is the radiologist, a medical doctor with extensive training, who ultimately interprets the X-ray and can detect and diagnose problems (American College of Radiology, n.d.). As Weber-Wulff (2016) points out, "it is generally not possible to construct a technological solution for the determination of plagiarism, since any definition is inevitably open for interpretation" (p. 626). In other words, it is the human who analyses the report, not the report itself, that diagnoses whether there is an issue that requires further investigation or treatment of a problem.

Online Exam Proctoring

During the COVID-19 pandemic, online exam proctoring services saw a surge in business, with the industry expected to reach a valuation of $325 Billion USD by 2025 (Talview, 2020). These are a suite of technologies clustered under the umbrella of "online proctoring" including lockdown browsers, identity authentication, and exam invigilation or monitoring (Dawson, 2020). Online exam invigilation can be performed synchronously during the exam or asynchronously by reviewing recordings of the exam after it has concluded.

Invigilation can be performed by a human or an artificial intelligence, with the former often being a more expensive option (Dawson, 2020).

The surge in online proctoring subscriptions during COVID-19 seemed to be another case of higher education institutions rushing towards technology to solve academic misconduct without fully considering its limitations and risks. Prior to the pandemic, researchers wrote about the importance of effective online course design to promote integrity, as well as the need to invest in training and professional development for online educators as ways to promote integrity (Berkey & Halfond, 2015). When schools flocked to online invigilation during COVID-19, students and scholars protested, citing privacy, data security, and accessibility as key factors (Chrysanthos, 2020; Dubiansky, 2020; Moro, 2020; Swauger, 2020). Equity is an additional consideration, as critics flagged the ways in which the algorithms embedded in the technology discriminate against students of darker skin tones (McKenzie, 2021; Rowland Williams, 2021; Parnther & Eaton, 2021). It is fair to say that online proctoring became one of the most polarizing educational technology debates of the COVID-19 pandemic. There remains, however, limited evidence about the effectiveness of online invigilation software to effectively detect academic cheating (Dawson, 2020; Eaton, 2020).

One useful outcome of the surge of online proctoring services is that guidance has emerged about how to implement this type of technology which include using online proctoring only as a last resort when no other options are available, ensuring high quality examination design, using only minimal restrictions, offering students an alternative (e.g., a different assessment task), ensuring that concerns related to equity, diversity, and inclusion are considered, offering the software is fully piloted before deployment, ensuring a "whole institution" approach is taken, and ensuring that privacy and data security laws are respected (Dawson, 2020). In other words, investing in online exam proctoring software requires not only paying a licensing fee, but also ensuring that educators, staff, and the institution itself are prepared to invest in training and assessment adaptation, including ensuring that assessments are high quality and appropriate. Online exam proctoring technologies are likely not going away; however, there is more work to be done to ensure they can be used appropriately, equitably, and fairly.

Artificial Intelligence and Large Language Models

The final technology discussed is artificial intelligence (AI) and specifically, LLMs such as GPT-3, or Generative Pre-trained Transformer 3, a technology that can produce human-like text based on a prompt. LLMs have existed for some time and their use among major mainstream media companies has become almost commonplace (Dans, 2019; Seabrook, 2019). Of note is the rate at which LLMs are developing and becoming more sophisticated means, and GPT-3 is more powerful and arguably useful than its predecessor, GPT-2. Since 2020, several free apps have emerged that will write poetry in the style of any poet (Rich, 2022) and those that claim to write literature reviews and help with research project design (see, for example: https://elicit.org/). Other AI apps not based on language, such as DALLE*E Mini, can generate an image based on any text prompt (Dayma & Cuenca, 2022).

It seems clear that artificial intelligence apps are developing quickly and there are exciting implications for teaching and learning; however, there is still a lot to think through. Educators have already been urging us to pay attention to how assessment practices might need to change as AI becomes more ubiquitous (Sharples, 2022). In the academic integrity research community, scholars are forecasting that contract cheating, or the outsourcing of academic work to a third party such as term paper mills, may evolve into students simply having an AI do the work on their behalf (Eaton et al., 2021; Lancaster, 2022).

If this happens, artificial intelligence writing apps could eliminate human ghostwriters entirely. It is possible to envision a future in which students might not have to engage in much academic writing at all, providing that they can prompt an AI app effectively. As it stands, many academic misconduct policies (at least in Canada) have some provisions to address outsourcing of academic work as a form of misconduct, either explicitly or subsumed under another category such as plagiarism (Eaton, 2021; Eaton et al., 2022; Stoesz & Eaton, 2020; Stoesz et al., 2019). There is currently limited guidance about how to address misuse of artificial intelligence as a breach of academic integrity. This is likely due, at least in part, to some fundamental questions that remain unanswered: Is it ethical to use AI for teaching, learning, and assessment? If so, how do we ensure the use of AI in educational context is, in fact, ethical? Who gets to decide what counts as ethical use of AI in education? Who decides what may or may not constitute academic misconduct when artificial intelligence is involved?

I have anecdotally heard comparisons between the use of AI today being analogous to the introduction of the calculator into classrooms a few decades ago. I would argue that this analogy is flawed for a couple of reasons. Parents or students had to buy calculators, which presented a financial barrier for some, but many AI apps are currently free, so there is no financial barrier to their use. Furthermore, calculators were a physical instrument, you held them and input numbers manually to generate a result. Artificial intelligence is not only an entirely digital tool; it is increasingly becoming embedded into existing technologies such as Word and Google docs. Recent advancements in predictive text generation, grammar checking, and so on, means that the boundaries between human and machine are becoming blurred. There is no longer a physical tool one has to buy, carry around, or enter input into. (Even as I write this, Word has suggested that I change the words “has to” to “must” in the previous sentence.)

As a scholar of academic integrity, I am not yet convinced that using AI apps would automatically constitute academic misconduct. I am worried about idiosyncratic responses to these apps in which individual educators become entrenched in polarized views that artificial intelligence is either good and must be adopted universally, or that it is evil and should be banned immediately. The potential for caustic and entrenched opinions that perpetuate philosophical and pedagogical divides worries me deeply. Of course, the debate is complex and more nuanced than I have time or space to address here, but I would say that artificial intelligence is "the next big thing", not only for academic integrity, but for education in general, and it merits our attention, as well as further inquiry.

Conclusions

As Lisa Vogt commented during the Academic Integrity Inter-Institutional Meeting (AIIIM), hosted online by the University of Manitoba in May 2022, when it comes to academic misconduct, "If you're looking for a silver bullet, I suggest you purchase a smoothie maker" (Vogt & Mercer, 2022). The context for this statement is that there is no "magic bullet" that will prevent academic cheating and educators would be better off focusing on student learning, rather than preventing cheating; a sentiment that has been espoused by academic integrity advocates worldwide (Bertram Gallant, 2008; Bretag & Mahmud, 2009; Morris, 2016).

The technological "arms race" (Mortati & Carmel, 2021; Thomas & Scott, 2016) does not promote academic integrity, and nor is the use of technology inherently (un)ethical. Technology comes, goes, and evolves. The question of how to use it effectively and ethically for teaching and learning persists. What is clear is that the message that educational technology scholars (Anderson et al., 2001; Garrison & Cleveland-Innes, 2005; Vaughan et al., 2013) have been saying for years about technology and teaching applies just as well to academic integrity: technology does not replace humanity. Understanding the benefits, as well as the limitations, costs, and impact of using technology to uphold academic integrity is foundational to making informed decisions about how, when, and if to use it.

References

American College of Radiology. (n.d.). What is a Radiologist? https://www.acr.org/Practice-Management-Quality-Informatics/Practice-Toolkit/Patient-Resources/About-Radiology

Anderson, T., Rourke, L., Garrison, D. R., & Archer, W. (2001). Assessing teacher presence in a computer conferencing context. *Journal of Asynchronous Learning Networks*, *5*(2), 1-17.

Berkey, D., & Halfond, J. (2015). Cheating, Student Authentication and Proctoring in Online Programs. *New England Journal of Higher Education*, 1-1.

Bertram Gallant, T. (2008). *Academic integrity in the twenty-first century: A teaching and learning imperative*. Hoboken, NJ: Wiley.

Bretag, T., & Mahmud, S. (2009). A model for determining student plagiarism: Electronic detection and academic judgement. *Journal of University Teaching & Learning Practice, 6*(1). http://ro.uow.edu.au/jutlp/vol6/iss1/6

Chrysanthos, N. (2020, May 22). 'You're being watched and recorded, every breath': Students unsettled by exam software. *The Sydney Morning Herxald*. https://www.smh.com.au/national/nsw/you-re-being-watched-and-recorded-every-breath-students-unsettled-by-exam-software-20200519-p54ucb.html

Clarke, R., & Lancaster, T. (2006). *Eliminating the successor to plagiarism: Identifying the usage of contract cheating sites*. Paper presented at the Second International Plagiarism Conference, The Sage Gateshead, Tyne & Wear, United Kingdom.

Dans, E. (2019, February 6). Meet Bertie, Heliograf And Cyborg, the new journalists on the block. *Forbes*. https://www.forbes.com/sites/enriquedans/2019/02/06/meet-bertie-heliograf-and-cyborg-the-new-journalists-on-the-block/?sh=669bf965138d

Dawson, P. (2020). Strategies for Using Online Invigilated Exams. https://www.teqsa.gov.au/sites/default/files/strategies-for-using-online-invigilated-exams.pdf

Dayma, B., & Cuenca, P. (2022, June 28). DALL·E mini: Generate Images from any text prompt. *Weights and Biases*. https://wandb.ai/dalle-mini/dalle-mini/reports/DALL-E-mini-Generate-Images-from-Any-Text-Prompt--VmlldzoyMDE4NDAy

Dubiansky, S. (2020, October 28). Students speak out on controversial lockdown browsers for online courses. *Technician Online*. http://www.technicianonline.com/news/article_c9693924-1996-11eb-869a-4b90407243a0.html

Eaton, S. E. (2020). E-Proctoring: Understanding the debate about invigilating remote exams. https://drsaraheaton.wordpress.com/2020/05/12/e-proctoring-understanding-the-debate-about-invigilating-remote-exams/

Eaton, S. E. (2021). *Plagiarism in higher education: Tackling tough topics in academic integrity*. Santa Barbara, CA: Libraries Unlimited.

Eaton, S. E., Mindzak, M., & Morrison, R. (2021, June 1). *The impact of text-generating technologies on academic integrity: AI & AI* Canadian Association for the Study of Educational Administration (CASEA), University of Alberta [online]. http://hdl.handle.net/1880/113569

Eaton, S. E., Stoesz, B. M., Godfrey Anderson, J. R., & LeBlanc-Haley, J. (2022, April 25). *Academic integrity through an equity lens: Policy analysis of universities in Atlantic Canada* American Educational Research Association (AERA) [online], San Diego, USA. http://hdl.handle.net/1880/114574

Garrison, D. R., & Cleveland-Innes, M. (2005). Facilitating cognitive presence in online learning: Interaction is not enough. *American Journal of Distance Education*, *19*(3), 133-148.

Hayden, K. A., Eaton, S. E., Pethrick, H., Crossman, K., Lenart, B. A., & Penaluna, L. A. (2021). A scoping review of text-matching software used for student academic integrity in higher education. *Education Research International, 2021*, 1-15. https://doi.org/10.1155/2021/4834860

Howard, R. M. (2001). Forget about policing plagiarism. Just teach. *The Chronicle of Higher Education*, B24. http://chronicle.com/article/Forget-About-Policing/2792

Lancaster, T. (2022, May 6). *Artificial intelligence led threats to academic integrity [online]* European Network on Academic Integrity (ENAI) 8th European Conference on Academic Integrity and Plagiarism (ECAIP) 2022, Porto, Portugal.

Lang, J. M. (2013). *Cheating lessons: Learning from academic dishonesty*. Harvard, MA: Harvard University Press.

McKenzie, L. (2021, April 6). Proctoring Tool Failed to Recognize Dark Skin, Students Say. *Inside Higher Ed*. https://www.insidehighered.com/quicktakes/2021/04/06/proctoring-tool-failed-recognize-dark-skin-students-say

Moro, J. (2020). Against cop shit. *Jeffreymoro,com*. https://jeffreymoro.com/blog/2020-02-13-against-cop-shit/

Morris, E. J. (2016). Academic Integrity: A Teaching and Learning Approach. In T. Bretag (Ed.), *Handbook of Academic Integrity* (pp. 1037-1053). Singapore: Springer Singapore.

Mortati, J., & Carmel, E. (2021). Can we prevent a technological arms race in university student cheating? *Computer*. https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9548108

Parnther, C., & Eaton, S. E. (2021, June 23). Academic integrity and anti-Black aspects of educational surveillance and e-proctoring. *Teachers College Record*. https://journals.sagepub.com/pb-assets/cmscontent/TCZ/Commentaries%20Collection/2021%20Commentaries/Academic%20Integrity%20and%20Anti-Black%20Aspects%20of%20Educational%20Surveillance%20and%20E-Proctoring-1650325575.pdf

Rich, S. (2022). The new poem-making machinery. *The New Yorker*. https://www.newyorker.com/culture/culture-desk/the-new-poem-making-machinery

Rowland Williams, J. (2021, November 1). Rethinking Assessment, Equity and Academic Integrity. *Diverse Issues in Higher Education*. https://www.diverseeducation.com/opinion/article/15280803/rethinking-assessment-equity-and-academic-integrity

Seabrook, J. (2019, October 14). The next word: Where will predictive text take us? *The New Yorker*. https://www.newyorker.com/magazine/2019/10/14/can-a-machine-learn-to-write-for-the-new-yorker

Sharples, M. (2022). New AI tools that can write student essays require educators to rethink teaching and assessment. *LSE Blog*. https://blogs.lse.ac.uk/impactofsocialsciences/2022/05/17/new-ai-tools-that-can-write-student-essays-require-educators-to-rethink-teaching-and-assessment/

Stoesz, B. M., & Eaton, S. E. (2020). Academic integrity policies of publicly funded universities in western Canada. *Educational Policy*. https://doi.org/https://doi.org/10.1177/0895904820983032

Stoesz, B. M., Eaton, S. E., Miron, J. B., & Thacker, E. (2019). Academic integrity and contract cheating policy analysis of colleges in Ontario, Canada. *International Journal for Educational Integrity*, *15*(4), 1-18. https://doi.org/https://doi.org/10.1007/s40979-019-0042-4

Swauger, S. (2020, June 7). Taking Back the Narrative of Ed Tech. *Shea Swauger*. https://www.sheaswauger.com/post/taking-back-the-narrative-of-ed-tech

Talview. (2016). *Online Proctoring is Trending: Here is All You Must Know*. https://blog.talview.com/a-complete-guide-to-online-remote-proctoring

Thomas, J., & Scott, J. (2016). UK perspectives on academic integrity. In T. Bretag (Ed.), *Handbook of Academic Integrity* (pp. 39-53). Singapore: Springer Singapore.

Vaughan, N. D., Cleveland-Innes, M., & Garrison, D. R. (Eds.). (2013). *Teaching in blended learning environments*. Athabasca University Press. http://www.aupress.ca/books/120229/ebook/99Z_Vaughan_et_al_2013-Teaching_in_Blended_Learning_Environments.pdf

Vogt, L., & Mercer, B. (2022, May 19). *Getting off the beaten path… Authentic assessments that enhance teaching, learning, and academic integrity [online]*. Paper presented at the Academic Integrity Inter-Institutional Meeting (AIIIM) 2022, Winnipeg, Canada.

Weber-Wulff, D. (2016). Plagiarism detection software: Promises, pitfalls, and practices. In T. Bretag (Ed.), *Handbook of Academic Integrity* (pp. 625-638). Singapore: Springer Singapore.

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Using Technology for Learning: Generalizable Lessons from Educational Technology Integration in Kenya

Utiliser la technologie pour l'apprentissage : Leçons généralisables de l'intégration des technologies éducatives au Kenya

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Abstract

This paper presents some initial findings from a multi-year partnership project on the integration of technology into the Kenyan education system. Specifically, qualitative evidence is presented on how results and lessons learned from the partnership project can be generalized and used by other research teams and projects using other technology platforms. Grounded in the critical theory of educational technology and using methodological strategies on the intersections of critical discourse analysis and critical ethnography, this paper examines technology integration in Kenyan public schools using the Learning Toolkit+ developed at the Centre for the Study of Learning and Performance at Concordia University in Montreal, Canada.

Keywords: LTK+; Kenyan education; Technology platforms

Résumé

Cet article présente certains résultats initiaux d'un projet de partenariat pluriannuel sur l'intégration de la technologie dans le système éducatif kenyan. Plus précisément, des preuves qualitatives sont présentées sur la façon dont les résultats et les leçons tirées du projet de partenariat peuvent être généralisés et utilisés par d'autres équipes de recherche et projets utilisant d'autres plateformes technologiques. Fondé sur la théorie critique de la technologie éducative et utilisant des stratégies méthodologiques à l'intersection de l'analyse critique du discours et de l'ethnographie critique, cet article examine l'intégration de la technologie dans les écoles publiques kenyanes à l'aide de la Trousse d'apprentissage+ développé au Centre d'études sur l'apprentissage et la performance de l'Université Concordia à Montréal, Canada.

Mots-clés : LTK+ ; éducation kenyane ; plateformes technologiques

Introduction

This paper is organized into four main sections starting with a brief overview of the Kenyan education system and the various vicissitudes in its evolution by tracing changes/reforms in curriculum development. In this respect, this paper focuses on how the Kenyan education system has evolved from its colonial groundings to realigning its education and curricula to the National Constitution (2010) to a more Westernized Competency-Based Curriculum under Vision 2030 and Kenya National Curriculum Policy (2015). Proceeding to examine the introduction/integration of technology in Kenyan education, this paper specifically takes examples and evidence from The Learning Toolkit+ (LTK+) project, to assess the pedagogical and societal successes and challenges during its technology integration. Finally, some generalizable lessons from qualitative research in Kenya in the Fall of 2018 are presented.

Objectives

There are two overarching research objectives:

1. To analyze the curriculum reform processes in Kenya through a reading of relationality between the historical, political, philosophical, societal, and post-colonial dynamics in Kenya since its independence; and
2. To examine the sustainability and scalability of a major technology integration project for early literacy and numeracy, The Learning Toolkit+ project.

Overview of Reforms in the Kenyan Educational System

This section presents an overview of the Kenyan education system to contextualize the debates and dynamics surrounding the integration of technology into the nation's educational system. Currently, Kenyan educational policymakers are in the process of revising the 8-4-4 curriculum with an aim to replace it with a competency-based curriculum. The erstwhile educational model is archaic, teacher-centered, authoritarian, and rigid (Jepkemei, 2017). The current system is also thought to be focused more on examination, inappropriate language training, and rote-learning of curricular content—all of which prevent the full realization of expected learning outcomes and learners' capabilities. The main motivation behind the reform is to develop competencies that are in line with the demand of the global economy which requires the applicability of core competencies outside the classroom and the transferability of competencies and skills in order to address world issues, such as systemic inequalities, in upskilling the workforce adequately.

Kenya's education system has come a long way since its independence in 1963. There have been numerous quantitative gains in the realm of education. Since 2003, primary education has been free, net enrollment has considerably increased, and near-gender parity in enrollment has been achieved. There has been a marked improvement in the distribution of educational resources across different regions of Kenya. Budget outlays of 10-15% have been a regular benefit since 2015/2016. Plans for infrastructure development, such as the electrification of 22,000 primary schools, are in the offing as well as plans to connect schools through a high-speed fiber-optic network. However, the statistical gains are often eclipsed when compared to the qualitative gains in the system. For example, recent research demonstrates that reading and numeracy levels in the country remain very low (Piper & Suilkowski, 2015; Uwezo, 2012, 2013, 2014), while there are inconsistencies in reading and numeracy levels across the rural-urban divide. These problems are compounded by high levels of student and teacher absenteeism, inadequate infrastructure, unequal availability of teachers across regions, lack of monitoring and accountability, and regional disparities (Uwezo, 2015). According to Onsomu et al. (2005) only 21% of the students in the sixth grade had a "desirable" level of reading. Similarly, Uwezo (2015) notes that the percentage of students with a minimum threshold in reading required to follow the reading requirements decreased between 1998 and 2000. A large study demonstrates that by 2013, Kenya (along with Tanzania and Uganda) had missed the target of ensuring access to quality education for its student population (2015). Another critical challenge for the Kenyan education system has been a dire shortage of teachers at almost all levels of schooling.

It was in this context that the current educational reform was articulated by the educational policymakers in Kenya. It is envisaged that the alignment of the Kenyan curriculum with the 2010 Constitution, the Basic Education Act 2013, the Kenyan Institute for Curriculum Development (KICD) Act 2013, and NESP ensures that the education system can create effective pathways for seamless transition of all children from one level to the next. It is also hoped that the curriculum aligns with the post-2015 sustainable development goals to guarantee lifelong, life-deep and life-wide learning. Kenyan educational policymakers are also cognizant of the need to harmonize Kenyan education with the international benchmarking regime, such as the International Bureau of Education.

The reorganized basic education curriculum framework replaces the 8-4-4 model with a 2-3-3-3 model (Inyega, et al., 2021). Under the new learner-centred system, the early years' education spans five years, including a two-year pre-primary and three-year lower primary education. Instead of "subjects," the pre-primary students have "learning areas" such as mathematics, language arts, environment, and religious education, in addition to mandatory community service learning. The students' learning performance is to be assessed over time in accordance with developmental milestones. Teachers assess students by observing their activities and by oral testing instead of the erstwhile examination-based assessment regime. Authorities gather data to further refine the system. Information and communication technologies (ICT) are integrated as learning tools in all learning areas (Jepkemei, 2017; Kaviti, 2018; Njeng'ere & Lili, 2017; Wanjohi, 2018).

Middle school education spans three years of upper primary (grades 4-6) and three years of junior secondary education (grades 7-9). In addition to the learning areas in early years education, students are exposed to science and technology education and social studies, with the learning of foreign languages as an available option. The reform retains the emphasis on ICT as a delivery and learning tool across all learning areas. The reform also adds a rigorous career counseling program to enable students to make informed choices for their future educational pursuits. The assessment at the middle school education level is a curious mix of 70% formative and 30% national examination (Inyega et al., 2021; Jepkemei, 2017).

Middle school education is followed by three years of senior school education (grades 10-12) targeted at learners 15-17 years of age. At this stage, the reform envisages the students to choose either of the three pathways, namely science, technical, engineering, and mathematics (STEM), arts and sports sciences, or social sciences in accordance with their envisioned interests and career paths. Regardless of the chosen pathway, the students will have to complete physical education hours as well as a minimum of 135 hours of community service outside of school. The idea of channeling students into relevant pathways is grounded in a constructivist paradigm of pedagogy pioneered by Jean Piaget (1968) and Lev Vygotsky (1987), which recognizes that each student/child has unique competencies that can be nurtured in specific pathways.

The new education reform in Kenya is clearly based on the constructivist student-centered pedagogical model that seeks to move away from the subject-oriented, teacher-centered, and norm-referenced educational system. Instead, the newly envisioned educational system aims to focus on students' competencies at the end of each cycle to identify their interests and abilities for different educational pathways leading to 21st-century skills (Njeng'ere & Lili, 2017) required for economic and societal development. The move from norm-referenced assessment to criterion-referenced assessment aims to gauge students' understanding and application of the skill and not just knowledge of the subject matter. Although the focus of the reform remains integration in and contribution to the economy, it also reignites previous efforts at making the education system relevant to society. While recognizing English as the lingua franca of the business and industrial world, the reform also recognizes the importance of bringing back the indigenous Kenyan languages "without resurrecting emotive feelings of a colonial past" (Inyega et al., 2021). The reform is also cognizant of the importance of indigenous knowledges, the role of language and culture in representations and identity formation, and the maintenance of cultural heritage. Finally, a major focus of the reform is to harness the potential and proven benefits of ICT systems to reach learners, including the marginalized, the vulnerable, and those with differing abilities. The guiding principle in this respect is learning—anytime, anywhere, anyhow.

In the next section, we elucidate the integration of technology into the Kenyan educational system. Specifically, we highlight an early literacy and numeracy software — Learning Toolkit (LTK+) that has been employed to realize the aims and objectives of the current educational reform in Kenya.

Conceptual Framework

Our study draws its theoretical and conceptual orientation from the critical theory of educational technology (Feenberg, 2002), which in turn, owes its epistemic roots to critical theory and critical pedagogy. The critical theory of educational technology retains all the aims and goals of critical pedagogy, except that the context of investigation is technology. True to its critical pedigree, the central focus of the critical theory of educational technology is to examine the possibilities that technology can offer in an educational context, either as a tool for the imposition of dominant social norms and control or as an educational tool for equitable and liberating educational experiences for learners.

In this context, the critical theory of educational technology aims to interrogate how educational institutions and educational systems in general appropriate and use technology for pedagogical purposes. Furthermore, it is concerned with finding out ways in which technology in education can lead to raising critical awareness in learners so that they can transform the world (Arshad-Ayaz, 2010; Feenberg, 2002, 2005) rather than becoming a tool of oppression and means of control. The critical theory of educational technology acknowledges the importance of the dynamic inter-relationships between different stakeholders in the learning context and seeks to examine various external influences on the process and politics of learning. To this end, critical scholars are interested in hearing and bringing in the voices of key stakeholders such as teachers, school administrators, students, parents, and technology-related support staff working in this field. Educational technology can offer opportunities for communication, dialogue, audiovisual aids, and diverse and unlimited resources, and can, therefore, be used as a great resource for educational purposes (Arshad-Ayaz, 2010; Feenberg, 2002, 2005; Franklin, 1999).

Technology Integration in Kenya via the Learning Toolkit+

The educational policymakers in Kenya are keen to explore and utilize the potential of ICT to advance educational reform. As Allen et al. (2017) points out, the ICT sector in Kenya is perceived by educators in public universities to be an asset for communicating with youth, and ICT could be used more effectively in the future as a resource for coordinating a more united national system (p. 7). The study points to mobile learning as a promising possibility thanks to the increasing accessibility of the Internet and the growing ICT infrastructure in the country. Cunningham (2016) suggests the wider adoption of ICT to support blended, online, and distance learning as a coping mechanism for the vast increases in enrolment within the past decade, given that there is not enough physical space or human resources to accommodate the increases. The benefits of increasing the use of technology include more effective support systems for more students, accommodation of diverse types of students, more diverse materials and languages, and access to online forums and learning communities (Cunningham, 2016; Piper et al., 2016). While the primary focus of Cunningham's arguments is the application of ICT in the higher education context, his arguments are also true for primary and secondary educational contexts. However, it will be prudent to heed Cunningham (2016) and Pipe et al. (2016) regarding expectations of ICT playing a major role in achieving the goals set by the current educational reform. Kenya needs a marked improvement in the infrastructure (networks and bandwidth), focusing on skills development and training, developing a clearly articulated institutional policy, working towards online content development, creating assessment policies, and implementing overarching change management systems to provide support. Political leadership and educational policymakers in Kenya seem to have grasped the message. The Ministry of Education, on the other hand, aims to mainstream ICT in “20,000 public primary schools, 6,000 public secondary schools, 22 provincial teacher training colleges, 2 diploma colleges, and 10 model e-learning centres for Adult and Continuing Education” (Abrami et al., 2014, p. 950). It is in this context that the Centre for the Study of Learning and Performance (CSLP) at Concordia University in Montreal, Canada, in partnership with the Government of Kenya and various institutional partners, designed and implemented an early literacy and early numeracy ICT-based intervention. Starting in 2013, the evidence-based and evidence-proven LTK+ was implemented in select Kenyan public schools in Nairobi and Mombasa.

The LTK+ is a suite of tools in English and French that includes *A Balanced Reading Approach for Children and Designed to Achieve Best Results for All* (ABRACADABRA or ABRA) — an early literacy tool; ELM, an early numeracy tool; READS, a digital library of reading resources; and ePEARL, a self-regulation tool. The LTK+ was conceived and developed by the CSLP at Concordia University in Montreal, Canada. The toolkit is available free of charge to institutions worldwide and has been successfully used in Canada, Northern Australia, China, Hong Kong, and Kenya. Plans are afoot for the introduction of LTK+ in Francophone Africa, notably in the Ivory Coast.

In the Kenyan educational context, three tools from the LTK+ namely ABRA, ELM, and READS have been employed thus far. ABRA is a collection of 32 learning tools aimed at improving the literacy skills (reading and writing) of children, including at-risk students (Bailey et al., 2016). According to Bailey et al. (2016), ABRA seeks a “balance between children’s code (i.e., phonics and word study) and meaning-based skill development (i.e., reading comprehension), and engagement with real literature” (p. 2). One of the cardinal features of the ABRA software is its flexibility and modular design, which allows it to be used by teachers in a variety of educational and pedagogical settings. To this end, Abrami et al.’s 2014 article contributes an in-depth exposé of the software.

Methodology

For the qualitative data collection, methods and insights from critical ethnography were used to collect and analyze narratives from key stakeholders in the Kenyan education system. Critical ethnography provides the researchers with intimate access to the subject perspectives, provides phenomenological accounts by the subjects—what Geertz (1973) calls “thick descriptions” —and direct access to the local culture and practices. In particular, we used ethnographic interviews, focus groups, and participant observation to collect data. The critical ethnographic data consisted of ethnographic interviews with teachers, school administrators, trainers, parents, policymakers, and faculty at the University of Nairobi’s Teachers Education Program. A total of 12 interviews were conducted. Additionally, we also conducted two focus groups with teachers and carried out participant observations at schools that are partnering in the implementation of LTK+ for early literacy and early numeracy education. While ethnographic interviews provided the depth of subjects’ experiences regarding the implementation process, the focus groups provided a breadth of perspectives on related issues. Specifically, in-depth interviews were conducted with one teachers’ union leader (Nairobi), two technical support staff (LTK+ related; Mombasa), two public schools’ principals (one in Nairobi and one in Mombasa), one vice-principal (Mombasa), eight teachers using ABRA for early grade literacy instruction, two teachers who were using the conventional methods for teaching literacy, and seven parents. In the discussion, the principals and vice-principal are referred to as administrators. Several University of Nairobi professors were also interviewed. These professors were directly and/or indirectly involved in the conceptualization and/or implementation of various technology-related projects over the years. Critical ethnographic methods (Carspecken, 1996; Madison, 2005) were combined with a critical discourse analysis (Fairclough, 1995; Gee, 2011; Jorgensen & Phillips, 2002) of the policy, curricular, and textbook data. The textual data corpus consisted of historical and current policy documents, historical and current curricular documents, and current social studies and language arts textbooks for classes pre-10. The textual data corpus was used to understand the historical context of reforms in the Kenyan educational system.

Sustainability and Scalability of Technology Integration in the Kenyan Education System

Insights from Two Qualitative Research Projects

One of the foremost challenges for any large technology integration project is the sustainability and scalability of the project. The sustainability of an educational technology integration project largely depends on two sets of factors. First, the technical efficacy, i.e., how well is the project designed? Does it deliver what it is intended for? The second set of factors that determines if the educational technology intervention is sustainable after the initial phase, marked by the enthusiasm of the early adaptors and the availability of funding expires, depends on several societal factors that include (but are not limited to): the reception of the project by the local culture, preparedness of the teachers, parental cooperation, relevance to local needs and ethos, buy-in by the educational leadership (political and bureaucratic) and school administration, and local technical expertise to sustain the project after the initial phase. Finally, the development of and investment in technology-related infrastructure is also important for the sustainability and scalability of the project. In terms of technical design and efficacy criteria, the LTK+ based early literacy and numeracy intervention has proven to be well articulated, well designed, flexible, and engaging.

A research project was designed to examine the societal and institutional conditions in Kenya to see if these conditions were conducive to the sustainability and scalability of the project. The qualitative research segment also sought to find out if the lessons learned could be generalized to benefit other research teams and projects. In this section, the results of the critical ethnographic research carried out in public schools in Kenya, particularly in public schools in Nairobi and Mombasa in Fall 2018 (see discussion on methodology above), are presented. The following discussion reflects the major themes that emanated from ethnographic interviews, narrative data, and focus groups conducted with teachers, school administrators, officials at the Kenya Institute for Curriculum Development, teachers’ union representatives, and parents.

Findings and Results

Is Kenyan Educational System Ready for Educational Technology-Assisted Competency-Based Education?

Research on the introduction/integration of educational technology, especially in developing societies, shows that it is important to ask the question: Is the country (including the society and the educational system) ready for educational technology? (Arshad-Ayaz, 2010). The readiness refers to societal buy-in and levels of infrastructure (equipment in the schools, provision of electricity, training levels for teachers and support staff, the sustainability of technical services, etc.). This is the question that was asked of all groups mentioned above. Overall, there seems to be a marked difference in opinions and perceptions between the different educational stakeholders (policymakers, university-based teacher education specialists, schoolteachers, school administrators, and parents). For instance, a key official at the Kenyan Institute for Curriculum Development (KICD) was confident but cautious, responding, “the question is not if the society is ready for educational technology. The question is: can society do without utilizing this proven key resource to raise literacy levels in a developing country like Kenya?” (Interview). The policymaker went on to explain that in the current global knowledge economy countries like Kenya, there is no choice but to raise literacy levels and prioritize education as a key resource for the economic and social development of the country. According to the policymaker, in a resource-strapped country like Kenya, governments have two broad choices. One is to provide massive amounts of money to ensure access to education (at all levels), training of teachers, etc., and the other is to utilize existing technology that is already developed and used elsewhere in the world. As the policymaker stated, "in the current day and age, the second option cannot be ignored. It is cost-efficient and is already proven to yield results". They told us that the KICD is examining several educational software options developed in countries such as the US, Canada, and Europe to assess their suitability for Kenyan educational needs.

In contrast, a group of professors in the teachers' education program at the University of Nairobi believed that Kenya needs to tread carefully before adopting educational technology developed by other countries, as purported by the research focus group at the University of Nairobi. The university professors pointed out several factors that can make an educational technology intervention successful or render it "yet another resource-draining fad." It must, however, be noted that the above views were not specific to ABRA and the LTK+ and reflect their perspective on the introduction of educational technology interventions in Kenya.

The professors specifically pointed to the recent one-tablet-per-student initiative of the Kenyan government. According to one professor,

> introduction of tablets in Kenya had a political taint. It was received with a lot of enthusiasm…but later some think the project was hijacked by persons for some political mileage. So even wherever they were received, they were received with some suspicion. Even the government found it was on the wrong footing because electricity is not within reach for every institution; even as we talk, not all schools are within an electrical grid.

Addressing the question of the Kenyan educational system's preparedness for the educational technology interventions, the focus group's view was summarized by one professor:

> The closest that that document *Medium Plan 2* [1] said about ICT was that ICT should be integrated into the education sector. Now, as my colleagues have already hinted, there was no unpacking of that to know which are the priorities, but in late 2012 towards 2013, when there was a general election, the ruling party at the time, which was campaigning to come to power, just out of the blue without any consultations, they said we want to give a tablet per child in every primary school. And that is where the problems began. Teachers were not aware. Many of them are not well-versed in ICT. They are struggling because they went to primary teacher colleges; some are university graduates, but they are not versed in ICT in the security of those gadgets.

The teachers in public schools, in general, were more supportive of the initiatives related to the introduction and integration of educational technology. Most teachers interviewed were categorically in support of such initiatives despite the problems they (and their schools) were facing in terms of teacher training, resources, etc. A distinct message from the teachers, especially those using educational software such as ABRA, was that society is welcoming of such initiatives. According to one teacher, "even the parents who themselves are not educated do realize the importance of technology and the value it has for educating their children." At the same time, they also point out that in the lower strata of society, this means students cannot work/practice at home as they do not have computers or tablets available at home. In general, there is an across-the-board realization that educational technology can alleviate the standards of education in the country. At the same time, there is an accompanying caution (and desire) that, unlike the previous educational reforms and initiatives, this time, the authorities will exercise due diligence before committing precious resources.

Buy-in From Educational Leadership and School Administration

In conjunction with the buy-in by society at large, one of the most important factors in the success of an educational technology project is the buy-in from school leadership and administration. Among the Kenyan public schools' leadership and administrators that were interviewed, there was almost a universal buy-in of the various initiatives related to the introduction and integration of educational technology in their schools. Despite trepidations about resources, these leaders and administrators seem to realize the potential of educational technology for learning and teaching. A principal of a public school in Mombasa stated, "I know that most kids enjoy learning by viewing so, in fact, I felt it's a great idea because it's going to assist the teachers to get the students to concentrate because it's something they'll be seeing and now their interesting will be captured" (Interview). It was

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[1] "The Second Medium Term Plan (MTP2) identified key policy actions, reforms, programmes and projects that the Government was to implement in the 2013-2017 period in line with the Government's priorities, the Kenya 2010 Constitution and the long-term objective of Vision 2030" (https://vision2030.go.ke/2013-2017/).

also clear that they were aware that the introduction of computer-assisted learning also brings an added workload for the teachers. However, this was something that, in their view, was surmountable. According to them, teachers, especially the younger ones, were enthusiastic about using the technology.

A vice-principal at another public school in Mombasa confirmed that the younger teachers show more enthusiasm for using educational technology. However, they also dispelled the view that older teachers were resistant to the use of ICT in classrooms. They wished that they could have all the teachers on board. However, there were still those who had not embraced it fully.

Specific to LTK+ and particularly ABRA, the majority of school administrators felt that it is working well beyond expectations. They identified the improvements in reading levels as a welcome sign that the software was working well. However, they also cautioned that it might be too soon to generalize success. One of the most encouraging signs of the success of LTK+ was peer education. While some students adapted to the technology almost immediately, for others, it was not instantaneous. However, they also noticed that the former group of students took it upon themselves to reach out to those who were struggling (or seemed not interested in using ICT). Almost all of the administrators interviewed were concerned about the resources, especially once the initial funding ran out. Administrators at one school in Mombasa were confident that they had built up (limited) capacity for technical support. As one administrator stated:

> LTK is technology-based. I'm sure it started, but not all schools have adopted it because this now depends on the financial position of the school. For instance, [the] servicing of computers, maybe some schools could have computers, but they couldn't afford the servicing. And maybe in some schools, they don't have the Internet, so…that can also be a problem. The willingness is there, but the resources are limited, more so in the public schools. We count ourselves lucky because we have a provision for [the] maintenance of computers.

Local Technical Expertise to Sustain the Project After the Initial Phase

Central to the sustainability and scalability of any educational technology project is capacity building among the local stakeholders. The CSLP (Authors and developers of LTK+) have been attentive to this cardinal principle. In Mombasa, the CSLP partnered with I Choose Life (ICL) and the Aga Khan Academies in this respect. The principle that underlines the capacity-building exercise is to train the trainers who, in turn, can train others at the school level. Thus, the capacity developed can sustain the project even after the return of the original trainers. Selected teachers from schools that are participating in using LTK+ are trained by a team of master trainers from the CSLP and ICL. Upon their return to their school, these teachers then train other teachers at their respective schools. According to one of these trainers, the criteria for the selection of teachers could include if they "are good in terms of 21st-century skills" since these skills are "really in tandem with…the LTK".

To sustain the capacity building, the trainers maintain a follow-up regime with the teachers. The follow-up support includes regular check-ups, advice, and support for networking, personal visits to the schools, auxiliary coaching, etc. A lengthy quote from one trainer explained the procedure for the follow-up:

> Yeah, we follow up that's a good question. I can tell you for sure if you are trained and no one…your morale goes down. So, we have made tremendous plans and strategies with the teachers we are dealing with. We have given them channels of sharing their feedback one: we have a WhatsApp group with the teachers and us staff and the Aga Khan staff also are part of the group. So, the teachers are sharing first-hand information from class and therefore you can be able to advise you can be able to upload you can be able to appreciate whatever they are doing in case they go they run into a problem. You can even troubleshoot from where you are because of that live sharing. Number two we have given them our numbers. Of course, so they can call sometimes.

According to those working at building capacity among the teachers using LTK+, one of the most important aspects is to have the teachers realize that technology (LTK+) adds value to their work and is not a burden. According to a trainer, "one way of adding value to teachers is by telling them that you can have an alternative to whatever you are doing. But if you tell them that it is something additional, they will actually just have resistance. So, first of all, we appreciate what they are doing first and then try to tell them". As such, ethnographic data from our research suggests that while the local technical expertise in this respect is limited, it is expected to grow, thus improving the chances for both sustainability and scalability of technology-assisted learning through software such as LTK+.

Localization of Content

One of the keys to engaging the students with the learning materials is the relevance of the material and content to the local knowledge. One of the major concerns about educational models, content, curricula, and software or platforms that are developed in the Global North and then exported to developing countries is the relevance of these to the local conditions, cultures, knowledges, and narratives (Naseem & Arshad-Ayaz, 2016; Steiner-Khamsi & Stolpe, 2006). As a professor at the University of Nairobi's focus group stated, "any content the children interact with, they want to see themselves in it. And so, if we are reading about our character, it could be from South Africa or any other country within the African continent or even elsewhere in the world, but is it relatable? Is the child able to relate to it? Is it culturally relevant?" When asked if they think LTK+ addresses these concerns about local relevance, the professors participating in the focus group were generally satisfied. One member of the focus group suggested it had been addressed in the software.

Public school teachers, especially those who are working with ABRA want to see more local content in the software. While they are generally appreciative of the software and the neutral vocals used by the narrators, they would like to see more Kenyan and even regional stories and voices used in the software. A number of teachers expressed a desire to see a Kiswahili version of ABRA that they could use to teach the language. Opinions about the relevance of the LTK+ to the local ethos, cultures, narratives, etc., were mixed. Improvement in localizing the local content, perhaps, will be the right step toward both sustainability as well as scalability.

Teachers' Buy-in and Resistance

Teacher preparedness lies at the heart of the sustainability of any pedagogical initiative. The application of the critical pedagogy framework compels researchers to understand teachers' perspectives on their teaching practices and teaching tools through social, pedagogical, and power lenses to evaluate the possible sustainability of any project. Teachers' narratives are important not only to highlight the gaps but also to understand the worldviews of the teachers, how teachers reflect on their teaching practices and teaching tools, and how teachers articulate their experiences and define the value of LTK+ in everyday teaching and learning practices.

Important clues to the long-term sustainability of the LTK+ can be gained from the study of the narratives of the teachers, which highlight their experiential understanding and thinking in terms of their daily practices and engagement with the LTK+. Teachers' narratives help us understand how teachers teach and the way students engage with the knowledge content in LTK+. As previously mentioned, eight teachers were interviewed from five schools that have piloted the use of LTK+, especially ABRA to teach primary and secondary school classes. In response to open-ended questions about the preparedness of public school teachers to use educational technology, two narratives were evident. First, there was enthusiasm among the teachers to use educational software like ABRA. Second, those who did not get a chance to be trained by the LTK+ team felt a little left out. Most teachers who were subsequently trained by their colleagues (the latter having received training from the LTK+ teams and their associates) felt that they were missing out on something. Furthermore, both groups felt that the training should be expanded, and more sessions and follow-ups offered. This is notably in contrast to the views of the trainer-of-trainers, who stressed that they were engaged in follow-up with the teachers initially trained. Teachers using ABRA were also less than satisfied with the opportunity to practice what they learned from the trainers. One teacher at a public school in Mombasa expressed that they would like to use ABRA in their free time to get more familiar with the software, stating, "we only have about an hour or so each week when we have the IT class. Even in there, a lot of time is spent on signing in by the students…there is no time for me…I feel I might forget some of the features of the program".

Not all Kenyan public-school teachers are totally on board with using educational software like ABRA, and ethnographic research revealed that resistance is multi-faceted. On the one hand, there seems to be resistance that has generational dimensions. Several public school administrators advised that older teachers seem less open to using the software than younger teachers. When asked to explain why, teachers and administrators indicated that it could be because the former group has had less exposure to technology than the latter group. It was also pointed out that the senior teachers are more familiar with the erstwhile pedagogical paradigm and, given the state of credential/knowledge renewal in Kenya, has not had many opportunities to be exposed to more current paradigms. One administrator told us that "normally, the professional development among Kenyan public-school teachers is in the form of one to two-days workshops which are considered time-off from work and are not taken too seriously." A professor who participated in the University of Nairobi's focus group confirmed this and went on to say, "once the teachers have been trained, they never get trained again."

Finally, conversations also reveal that the teachers' heavy workloads were also a factor in the teachers' resistance to learning about and employing educational software in their classrooms. A number of teachers interviewed for the project expressed these sentiments. Several teachers believe that they already had a heavy workload and that learning the software did not bring them additional recognition or remuneration. While the school administrators generally agreed with the remuneration part, they did not agree with the lack of recognition argument. It was, for example, pointed out by a number of administrators that the "keenness of the students to learn via ABRA was its own recognition and reward." As much as it is not a software-related issue, it is safe to say that for any educational technology intervention to be sustainable and scalable, it is important to bring the teachers onboard.

Discussion

This paper sets out to examine:

a) the curriculum reform processes in Kenya, and
b) the sustainability and scalability of the LTK+ project in the overall context of the latest (ongoing) curricular reforms in Kenya.

Below is the concluding discussion of the research results, i.e., the curriculum reform process in Kenya, especially with reference to the introduction/integration of technology in education and the factors that impact the potential for the Toolkit to be an effective, sustainable technology tool for education in Kenya.

Objectives of Educational Reforms in Kenya

The discourse analysis of the curricular reform shows that there are two major motivations behind the reform process. First, Kenyan policymakers aim to transform the educational system to comply with the demands of the global productive processes (the global financial landscape and the global labor pool). As conceived, the reform is expected to give Kenya a larger stake in the regional as well as the global production landscape. Juxtaposed with this is the objective to produce a national workforce that is flexible, tech-savvy, and sectorally mobile.

A second educarional reform objective is to develop a Kenyan citizenry that is critical, communally responsible, and cohesive. Conversations and ethnographic research with educational stakeholders in Kenya show that, in general, the stakeholders are cautiously optimistic about the ongoing curricular reform in the country. At the same time, there are several areas in which trepidations were expressed. It was, for instance, pointed out by several university professors in the teachers' education program that Kenyan education, once again, is moving towards an imported model of education without sufficient preparation and thought into the pre-planning phase. As one policymaker in Nairobi commented, "they are again adopting a western model without a) sufficient thought into its relevance to Kenyan needs and b) without sufficient preparation." Several university professors, public school administrators, and public school teachers also expressed reservations that the competency-based model being implemented without sufficiently preparing the teachers first. While the Kenyan educational policymakers stressed that the reform process is based on national conversations and feedback from key stakeholders, a number of our respondents contested these claims and pointed to a lack of consultancy process before the policy was articulated.

Is Kenya Ready for Technology-Assisted Competency-Based Education?

Perceptions and views of Kenyan educational stakeholders on the issue of technology integration in education, a key thrust of the reform, also presents a cautiously optimistic yet critical picture. Although the focus of the reform remains integration in and contribution to the economy, it also reignites previous efforts at making the education system relevant to society. While there is an across-the-board consensus that integration of technology in the educational realm is unavoidable, Kenyan academia cautions against a hasty adoption of technology in the education without first weighing the costs. It was repeatedly pointed out that before investing large sums of money, it is prudent to first take stock of the ground realities that include lack of infrastructure (severe in some regions and sectors), levels of teachers' preparedness to use technology for educating purposes, perceived usefulness, effects on teachers' workloads, etc. These reservations reflect the insights from the literature that cites regional examples to urge a cautious approach. Scholarship in the area shows that Nigeria has a much larger number of Internet users (as reported by Edo et al., 2019, there are 123.49 users per 1000 in Nigeria VS 46.87 users per 1000 in Kenya) and that Nigerian students and teachers have more mobile phones, laptops, tablets, and personal computers. Yet, they still face high dropout rates and low literacy levels (Edo et al., 2019) and have failed to integrate technology into the classrooms (Ameen et al., 2019). Thus, a prudent, well-thought-out approach is required before Kenya invests heavily in educational technology. Interestingly, the public school teachers interviewed indicated that despite the shortcomings in the system, educational technology shows great promise for raising literacy and numeracy levels.

Ethnographic research on the issues of sustainability and scalability of the LTK+, the technology integration project for early literacy and numeracy, revealed that issues such as the readiness of the Kenyan society to adopt and make efficient use of educational technology for alleviating literacy and numeracy levels, there is a cautious optimism accompanied by hopes and expectations of due diligence by the government. It is generally believed by the stakeholders that the efficacy of educational technology initiatives largely depends on an accompanying development in infrastructure. Any lag in the latter will negatively affect the former.

Technology Buy-in by Stakeholders

Specific to the integration and use of the LTK+, especially ABRA, the research results point to an impressive buy-in by the policymakers as well as the administrators and teachers in the public schools in Kenya. While there is some resistance, especially from the older generation of teachers, most teachers interviewed were enthusiastic about the results produced from the use of ABRA which showed an increased keenness and excitement among the students to use the software. Specific recommendations by teachers to improve the software include increased localization of content, enhanced training, increased follow-up by the trainers, integration of LTK+/ABRA in more subjects (than just language instruction), improved infrastructure, especially Internet availability and bandwidth, and regulation of teachers' workloads.

While generalizability is never a concern for critical qualitative research, a key question for any critical qualitative research is whether the insights from the research process and/or results can be useful for other researchers (even those using different methodological strategies). This research offers several such insights that other teams of researchers can benefit from. First, it is important to ask questions about the readiness of a society to receive and utilize any technology and educational technology in particular. While answers to this question vary from one context to the next, they give key insights about the timing and scope before the technology is introduced in a particular society. Second, and similarly, it is important to ascertain particular national and societal ethos to gauge the level of societal buy-in of any technological intervention. Our research provides a thick description of stakeholders' perceptions about the societal buy-in in Kenya along with more personalized narratives of teachers' buy-in and resistance. Finally, our research points out the importance of examining the relevance of technology-assisted education to the local cultures and ethos. This is another strategy that can be generalized and used by other research teams.

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References

Abrami, P., Wade, A., Lysenko, L., Marsh, J., & Gioko, A. (2014). Using educational technology to develop early literacy. *Education and Information Technology, 21*, 945-964. https://doi.org/10.1007/s10639-014-9362-4

Allen, L. R., Garst, B. A., Bowers, E. P., & Onyiko, K. K. (2017). building a youth development system in Kenya: Comparing Kenyan perceptions of local and national systems. *Journal of Youth Development, 11*(3), 72-88. https://doi.org/10.5195/JYD.2016.461

Ameen, S. K., Adeniji, M. S., & Abdullahi, K. (2019). Teachers' and students' level of utilization of ICT tools for teaching and learning mathematics in Ilorin, Nigeria. *African Journal of Educational Studies in Mathematics and Sciences, 15*(1), 51-59. https://doi.org/10.4314/ajesms.v15i1.5

Arshad-Ayaz, A. (2010). Of mice and men: Educational technology in Pakistan's public school system. *Journal of Contemporary Issues in Education, 5*(2), 5-23. https://doi.org/10.20355/C51S3P

Bailey, B., Arciuli, J., & Stancliffe, R. J. (2016, June 20). Effects of ABRACADABRA literacy instruction on children with autism spectrum disorder. *Journal of Educational Psychology, 109*(2), 257-268. https://psycnet.apa.org/doi/10.1037/edu0000138

Carspecken, P. (1996). Critical ethnography in educational research. Routledge.

Constitution of Kenya (2012). https://www.constituteproject.org/constitution/Kenya_2010.pdf

Cunningham, M. (2016, September). Technology-Enhanced Learning in Kenyan Universities. *IEEE Technology and Society Magazine, 35*(3), 28-35. https://doi.org/10.1109/MTS.2016.2593238

Edo, S., Okodua, H., & Odebiyi, J. (2019). Internet adoption and financial development in sub-saharan Africa: Evidence from Nigeria and Kenya. *African Development Review, 31*(1), 144–160. https://doi.org/10.1111/1467-8268.12370

Fairclough, N. (1995). Critical discourse analysis: The critical study of language. London and Longman.

Feenberg, A. (2002). Transforming technology: A critical theory revisited. Oxford: OUP.

Feenberg, A. (2005). Critical theory of technology: An overview. *Tailoring biotechnologies, 1*(1), 47-64.

Franklin, U. (1999). The real world of technology. Revised edition. House of Anansi Press.

Gee, J. (2011). An introduction to discourse analysis: Theory and method. Routledge.

Geertz, C. (1973). The Interpretation of Cultures: Selected Essays. Basic Books.

Inyega, J., Arshad-Ayaz, A., Naseem, M., Mahaya, E., & Elsayed, D. (2021). Post-Independence Basic Education in Kenya: An Historical Analysis of Curriculum Reforms. Forum for International Research on Education.

Jepkemei, E. (5 April 2017). Curriculum Reform: Is it worth the trouble? https://www.standardmedia.co.ke/article/2001235123/curriculum-reform-is-it-worth-the-trouble

Jorgensen, M., & Phillips, L. (2002). Discourse analysis as theory and method. SAGE.

Kaviti, L. (2018). The New Curriculum of Education in Kenya: a Linguistic and Education Paradigm Shift. *Journal of Humanities and Social Science, 2*(23), 84-95.

Kenya Basic Education Act 14 (2013). http://www.kenyalaw.org/lex/actview.xql?actid=No.%2014%20of%202013

Kenya National Curriculum Policy (2015). https://www.lextutor.ca/kenya2/nat-curric-policy_2015.pdf

Kenya Vision 2030. https://vision2030.go.ke

KICD Act (2013). https://kicd.ac.ke/wp-content/uploads/2017/10/KICDACT2013-1.pdf

Madison, D. (2005). Critical ethnography: Methods, ethics and performance. Sage.

Naseem, M. A., & Arshad-Ayaz, A. (2016). Knowledge imperialism: Education and domination in the neo-liberal era. In K. Gray, & H. Bashir (Eds.), Eastward Bound: The politics, economics, and pedagogy of Western higher education in Asia and the Middle East. Lexington/Rowman and Littlefield.

Njeng'ere, D., & Lili, J. (2017). The why, what and how of competency-based curriculum reforms: The Kenyan Experience. In UNESCO's Series on Current and Critical Issues in Curriculum, Learning and Assessment. https://unesdoc.unesco.org/ark:/48223/pf0000250431

Onsomu, E., Nzomo, J., & Obiero, C. (2005). The SACMEQ II Project in Kenya: A study of the conditions of schooling and the quality of education. Harare and Nairobi: Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) and Kenya Ministry of Education, Science and Technology.

Piaget, J. (1968). Genetic Epistemology: A series of lectures delivered by Piaget at Columbia University, Published by Columbia University Press, translated by Eleanor Duckworth. http://www.marxists.org/reference/subject/philosophy/works/fr/piaget.htm

Piper, B., Suilkowski, S. S., Kwayumba, D., & Strigel, C. (2016). Does technology improve reading outcomes? Comparing the effectiveness and cost-effectiveness of ICT interventions for early grade reading in Kenya. *International Journal of Educational Development, 49*, 204-214. https://doi.org/10.1016/J.IJEDUDEV.2016.03.006

Piper, B., & Zuilkowski, S. S. (2015). Teacher coaching in Kenya: Examining instructional support in public and nonformal schools. *Teaching and Teacher Education, 47*, 173-183. https://doi.org/10.1016/j.tate.2015.01.001

Steiner-Khamsi, G., & Stolpe, I. (2006). Educational import in Mongolia: Local encounters with global forces. Springer.

UWEZO. (2012). Are our children learning? Nairobi: Twaweza.

UWEZO (2014). Are our children learning? Nairobi: Twaweza.

UWEZO (2015). Are our children learning? Nairobi: Twaweza.

UWEZO (2016). Are our children learning? Nairobi: Twaweza.

Vygotsky, L. (1987). The collected works of L. S. Vygotsky. Eds. R. Rieber & A. Carton. Springer.

Wanjohi, A. M. (April 14, 2018). Critical review of 8-4-4 education system in Kenya. Schools Net Kenya. https://www.schoolsnetkenya.com/critical-review-of-8-4-4-education-system-in-kenya/

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Student-Generated Questions Fostering Sustainable and Productive Knowledge Building Discourse

Questions générées par les élèves Favoriser un discours sur le renforcement des connaissances durables et productifs

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Abstract

The role of questions in student learning is well recognized. However, the controversial issue of who should pose questions that direct inquiry continues: teachers or students? One perspective advocates that teachers generate questions as it assumes that students cannot generate high-quality questions. In contrast, Knowledge Building, a pedagogical approach that advocates transforming schools into knowledge-creation organizations, emphasizes student agency in generating authentic questions as they try to understand the world around them. This study examined the extent to which elementary students could generate questions and explore how student-generated questions help Knowledge Building discourse progress. Comparing question threads (i.e., a series of online notes started with questions) and non-question threads (i.e., a series of online notes not started with questions), we noticed that questions posted by students engaged them in sustainable and progressive discourses, which is central to Knowledge Building. Moreover, the content analysis of the data revealed that the threads starting with questions were more likely to end up with productive threads than the non-question threads.

Keywords: Knowledge building; Student-generated questions; Productive discourse; Sustainable discourse; Science education

Résumé

Le rôle de question pour l'apprentissage des étudiants est vraiment reconnu. Mais une question controversée est qui va poser les questions qui dirige l'enquête, les professeurs ou les étudiants? Une perspective souligne que les professeurs produisent les questions a cause que les étudiants ne sont pas capables de créer des questions de haute qualité. Une autre perspective souligne l'agence étudiante en posant les questions et suppose qu'un échec des questions généré par les étudiants peuvent avoir un résultat d'échec de la consolidation des connaissances. Cet étude examine le degré que les étudiants élémentaire sont capables de générer questions et explore comment les questions générées des étudiants aident la consolidation des connaissances du progrès de discours. Dans la comparaison d'un fil de questions (un série de notes en ligne qui ont commencé avec des questions) et un fil de non-questions (une série de notes en ligne non commencé par des questions), on a réalisé que les questions posé par les étudiants les ont engagés dans un discours progressive et durable. Cela est centrale dans la consolidation des connaissances. De plus, l'analyse du contenu des données a révélé que les fils qui ont commencé avec des questions était plus probable a finir avec des fils productive compare au fils de non-questions.

Mots clés: Développement des connaissances ; Questions posées par les étudiants ; Discours productif ; Discours durable ; Enseignement scientifique

Introduction

Researchers and educators have investigated the nature and types of questions and recognized the importance of students' questioning for learning and teaching (Chin & Osborne, 2008; Graesser & Olde, 2003). Questioning represents a thinking processing skill; it is "structurally embedded in the thinking operation of critical thinking, creative thinking, and problem solving" (Cuccio-Schirripa & Steiner, 2000, p. 210). There are different classifications of questions based on cognitive levels involved in responding to questions, i.e., input, processing, and output questions (Pizzini & Shepardson, 1991), the process of conceptual change, i.e., exploration, elaboration, and consolidation questions (Watts et al., 1997), and whether questions can lead to open investigations, i.e., investigable and non-investigable questions (Chin & Kayalvizhi, 2002).

Student-generated questions have the potential to direct students' learning and drive their knowledge construction, enhance their discourse quality, enable them to monitor and evaluate their learning progress, and sustain and even increase their interest and curiosity in learning topics. Furthermore, students' questions can help teachers diagnose students' understanding, stimulate further inquiry, provoke learning reflections, and evaluate students' high-order learning skills (Chin & Osborne, 2008).

These benefits of student-generated questions are essential to Knowledge Building, a pedagogical approach that advocates transforming schools into knowledge-creation organizations. Knowledge building usually starts with students' authentic questions while they are making sense of the world around them (Scardamalia, 2002). This knowledge-building approach supports them to take responsibility to sustain discourse and improve ideas by pursuing questions, theorizing, working with information, supporting discussions, and synthesizing diverse ideas (Chen et al., 2017; Scardamalia & Bereiter, 2006). Idea improvement is about continually asking whether a theory (i.e., student-generated explanations in Knowledge Building) could explain existing phenomena, identifying the weakness of theories, broadening explanations to encompass more new facts, achieving greater explanatory coherence, and deepening explanations of why theories work (Thagard, 2007). Discourse sustainability is important because a community that fails to sustain the discourse may only have knowledge sharing rather than knowledge construction or progressive inquiry discourse (van Aalst, 2009).

In the knowledge-building context, questions are usually classified as factual questions (e.g., who, what, where, and when questions) and explanatory questions (e.g., why or how something works questions) (Hakkarainen, 2003; Lai & Law, 2013; Resendes, 2014). Zhang et al. (2018) added the sub-category of idea-deepening questions to differentiate whether a question is asked to initiate or to sustain an inquiry. Scardamalia and Bereiter (1992) argued that compared to basic information questions (i.e., factual questions), wonderment questions that reflected students' curiosity and puzzlement had a greater potential for advancing students' conceptual understanding. Our explanatory study (Khanlari et al., 2017) with a dataset from one Grade 4 class suggested that student-generated questions tended to lead to longer inquiry threads and were more likely to lead to more productive threads in science learning. With a larger dataset and more participants, this study aimed to examine further the extent to which students in a knowledge-building community could generate factual and explanatory questions, and whether student-generated questions could engage fellow students in sustainable discourse and community knowledge advancement in science learning.

Literature Review

Student Generated Questions

As briefly discussed in the introduction, student-generated questions have several documented benefits that can be classified into the following aspects. First, student-generated questions can help students shift from passively acquiring knowledge to actively constructing their knowledge by negotiating a fit between prior knowledge and new information (Osborne & Wittrock, 1985). Also, questions can initiate hypothesizing, predicting, thought experimenting, and explaining processes and may also help students construct missing pieces in their knowledge structures or resolve their understanding conflicts (Chin & Brown, 2000). Second, questions foster the development of students' discourse and discussions. When students co-construct or co-create knowledge with their peers, questions are embedded in their discourse, and these questions help to scaffold ideas, encourage learners and peers to further think about and elaborate on their ideas, and negotiate meaning in their construction space (Chin & Osborne, 2008). Third, questions can help students self-regulate their understanding and learning, for instance, helping detect inconsistencies between their prior knowledge and new information (Black et al., 2002). Finally, questions can help students take control and ownership of their learning and may enhance their interest in learning and motivation (Chin & Osborne, 2008). For example, Chin and Kayalvizhi (2005) found that the Grade 6 students they studied described being "happy," "excited," or "proud" about posing their investigating questions.

Previous studies have researched how to support students in generating questions and how student-generated questions may influence students' learning performance and engagement positively. One study by Hsu and Wang (2018) found that an online puzzle-based game learning system and a student-generated question strategy enhanced students' algorithmic thinking skills and willingness to participate in the activity. As well, Yu (2009) created an online student question generation system to support students' learning activities by adopting various scaffolding techniques and mechanisms. She found that scaffolding (e.g., reflective social discourse, process prompt, process model) embedded in the system was perceived to provide high levels of support.

Similarly, other studies found that in the Knowledge Forum, scaffolding such as "I need to understand," "I wonder why," and "this theory cannot explain" can be used to support students in generating questions and building theories (Scardamalia, 2004; Zhu et al., 2018).

Concerning the nature and types of student-generated questions, a common distinction is factual questions and explanatory questions (Hakkarainen, 2003; Lai & Law, 2013; Resendes, 2014). Factual questions (i.e., who, what, where, and when) seek information and definitions, whereas explanatory questions (i.e., how and why) seek reasons and mechanisms. Explanatory questions are crucial for progressive inquiry because they cannot be satisfactorily answered without elaborating on an explanation (Hakkarainen, 2003). Further, explanatory questions can push inquiry forward in new and promising directions. Factual questions, in contrast, tend to produce fragmented pieces of knowledge, although these could potentially serve as evidence to justify theories (Resendes, 2014).

Knowledge Building and Knowledge Forum

Knowledge building is not about getting the correct answers as quickly as possible. Instead, it concerns improving ideas and advancing collective knowledge on problems and questions of value to the community. To achieve this goal, asking deep and rich questions that can spark and sustain a prolonged Knowledge Building inquiry is crucial (Resendes & Dobbie, 2017).

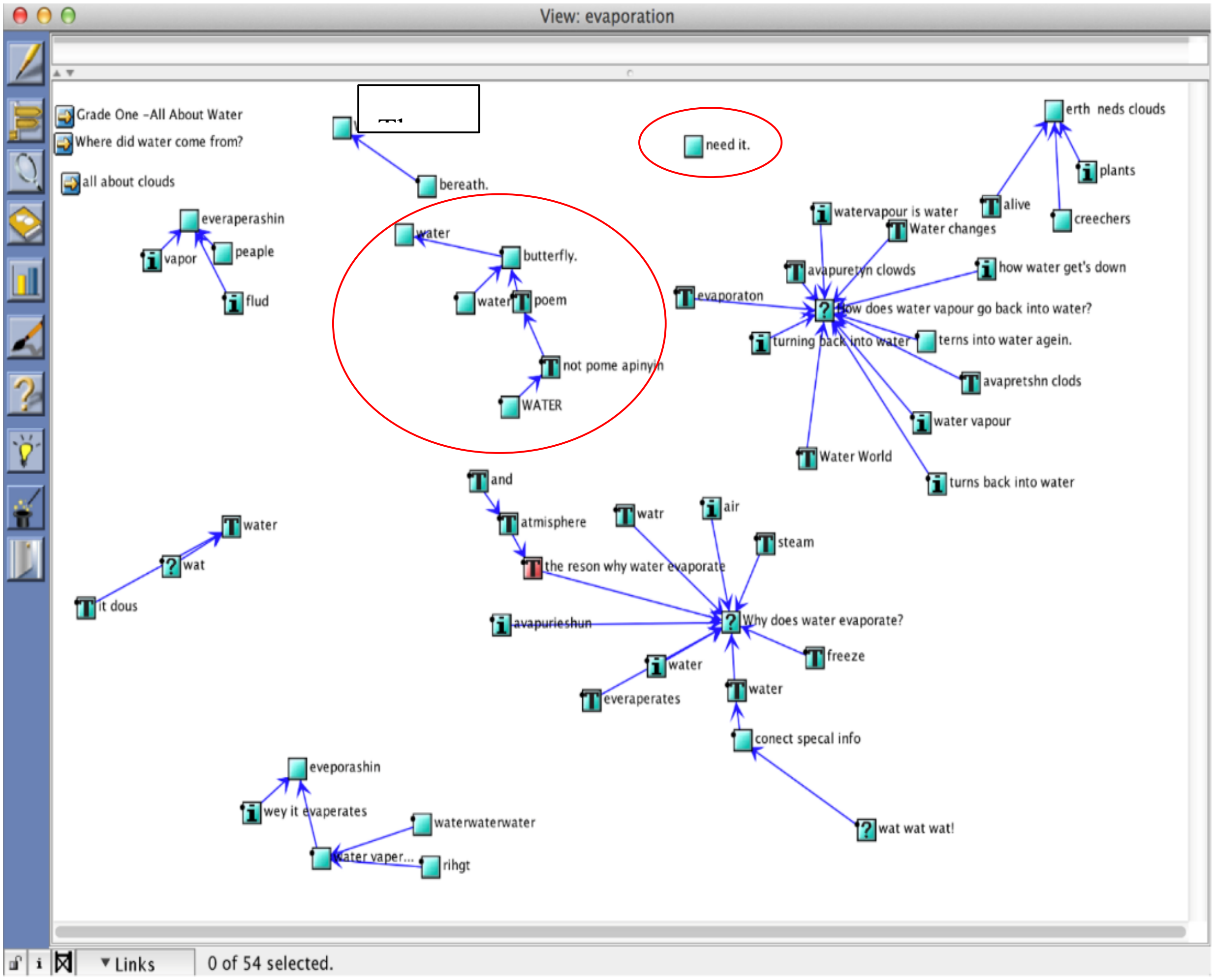
In Knowledge Building, students take responsibility for setting goals, engaging in long-range planning, using different ideas to spark and sustain ideas, monitoring idea coherence, and assessing their work (Scardamalia, 2002). These responsibilities align with the functions and advantages of student-generated questions. Knowledge building places students' ideas at the centre, and student-generated questions initiate and drive their collaborative inquiry. A key knowledge-building principle, engaging students in real ideas and authentic problems, means focusing on the ideas that students come up with and the questions they care about, not what others decide as engaging (Scardamalia, 2002). Rather than solving given problems, students learn to mine the world around them for interesting issues and challenges and discover opportunities for building theories and knowledge advancement. In pursuing real ideas and authentic problems, students engage in sustained creative work with ideas through Knowledge Building discourse (Scardamalia & Bereiter, 2006).

Knowledge building discourse can happen in physical classrooms. Students can share ideas and ask questions through face-to-face "Knowledge Building talk" (Reeve et al., 2008). In Knowledge Building talks, all class members, including the teacher, sit in a circle (ideally) so everyone is at the same level and can see and talk to everyone else.

Figure 1 shows the interface of Knowledge Forum (version 4), an online platform supporting students' collaborative knowledge creation discourse (Scardamalia, 2004). As one of the earliest computer-supported collaborative learning (CSCL) environments, Knowledge Forum shares the benefits of collaborative learning technologies such as supporting collaboration skills and knowledge creation, making social interactions a source of cognitive advancement, improving the equality of participation and depth of analysis, keeping track of students' collaborative work, and enabling time and space flexibility (Campbell & Stasser, 2006; Fjermestad, 2004; Resta & Laferrière, 2007). Furthermore, Knowledge Forum has several specific affordances. First, it provides scaffolds to support students' question development and theory building (Scardamalia & Bereiter, 1983), and these scaffolds can be used in any order and customized to meet students' emergent needs (Zhang et al., 2011). Another feature of Knowledge Forum is the rise-above function which allows users to connect, synthesize and archive different ideas, identify gaps, and plan for future inquiry directions in a public space open to all community members. Furthermore, various analytical tools can be used to assess students' activities, social networks, semantic networks, and discourse to improve the awareness of students and teachers concerning their Knowledge Building (Chen & Zhang, 2016; Zhu & Kim, 2017).

Figure 1

The Interface of Knowledge Forum v.4 Used by the Participants



Sustainable and Productive Knowledge Building Discourse

A thread-level analysis of Knowledge Building discourse helps researchers understand the development of ideas, whether ideas are improved, and the extent to which questioning contributes to collective knowledge advancement (Lai & Law, 2013). Previous research mainly identified threads in two ways. First, some researchers (Hewitt, 2005; Hewitt & Teplovs, 1999) adopted the natural relations between notes in the Knowledge Forum when discussing discussion threads and considered a thread as a series of physically connected notes linked by building on or referencing relationships (Figure 1). Another way of classifying threads is based on the semantic meaning of notes. For instance, Zhang et al. (2007) defined an inquiry thread as a sequence of notes that address the same principal issue or topic. In order to classify threads, researchers usually need to download and read all Knowledge Forum notes to identify the principal problems, and divide notes into different sub-inquiries, namely inquiry threads based on the main issue or topic they aim to address (Yang et al., 2016). The sustainability of discourse can be measured by the length of each thread (Khanlari et al., 2017).

In addition to the sustainability of the threads, it is important to investigate whether the discourse is advancing community knowledge (Bereiter et al., 1997). The essence of Knowledge Building is the production and continuous improvement of ideas to advance community knowledge (Scardamalia & Bereiter, 2003). Therefore, thematic analysis is usually conducted to examine which types of threads demonstrate idea improvement. For instance, the "ways of contributing" framework (Chuy et al., 2011) categorizes students' contributions into six main categories (i.e., questioning, theorizing, obtaining information, working with information, synthesizing and comparing, and supporting discussion) and 24 sub-categories (such as asking explanatory questions, proposing an explanation, improving an explanation, or synthesizing available ideas). Employing this framework, Chen et al. (2017) classified threads into productive and non-productive threads based on whether there is an "improving an explanation" code within a thread. Their rationale for doing so is if any note in a thread is coded as improving an explanation, this thread demonstrates students advancing their initial explanation in relation to their questions. Otherwise, the thread was considered non-productive because students did not improve their ideas or explanations in relation to questions.

A few studies suggest the relationships between student-generated questions and their idea improvement (i.e., the productiveness of threads) in Knowledge Building. For example, Scardamalia and Bereiter (1992) compared text-based questions (i.e., answers that can be found in the text) and knowledge-based questions (i.e., questions generated out of students' effort to make sense of the world and to extend their knowledge). They argued that among knowledge-based questions, the wonderment questions, which reflected students' curiosity and puzzlement and aimed at constructing explanations or resolving discrepancies, have a greater potential for advancing students' conceptual understanding. Along this line of research, some studies (Hakkarainen, 2003; Lai & Law, 2013) differentiated factual and explanatory questions. For instance, Hakkarainen (2003) found that Grade 5 and 6 students generated much more explanatory questions (89.7%) than factual questions (10.3%), and students' explanations were at a relatively high explanatory level. He concluded that students generated intuitive theories and searched for explanatory scientific information to answer their questions. Lai and Law (2013) explored the relationship between the level of questions and the epistemic complexity (i.e., fact versus explanation, unelaborated versus elaborated) of knowledge constructed by Grade 6 and Grade 10 students. They found for the Grade 10 students, there was a significant positive correlation between the average level of questions of a thread and students' average level of explanations, suggesting that a thread with higher-level questions was more likely to contain high-level knowledge.

The Current Study

The literature reviewed above suggests the importance of student-generated questions to their learning in general and Knowledge Building in specific and explores the relations between questioning and discourse. However, there is a need for more focused studies to examine the influence of questioning on the sustainability and productiveness of Knowledge Building discourse. The current study aimed to address these gaps. More specifically, the following research questions guide this study:

1. To what extent can students generate questions in Knowledge Building discourse?
2. What is the difference between factual, explanatory and non-questions (i.e., sentences that are not factual or explanatory questions) in affecting the sustainability of their Knowledge Building discourse?
3. How do explanatory, factual, and non-question threads affect the productiveness of Knowledge Building discourse?

Methods

Participants and Context

The participants of this study were 102 primary school students from Grades 1-5/6 in a private lab school located in a larger city in North America. In each class, there were 20-22 students with a similar number of girls and boys. The school had used the Knowledge Building pedagogical approach and Knowledge Forum technology for about three decades, with the approach usually being introduced to the students in junior kindergarten and the technology often being introduced in Grade 1. Therefore, the knowledge-building culture was well established in the school, and the students and teachers felt comfortable with the Knowledge Building pedagogical approach and technology.

At the time of this study, in a typical semester in each class, science learning was organized around an overarching topic, such as water in Grade 1, trees in Grade 2, and fungus in Grade 3 (see Table 1 for a complete list of topics). The Knowledge Building of each class started with Knowledge Building talks in which students and their respective teachers discussed what questions, ideas, and theories they cared about and wanted to inquire about more. In this process, students were likely to bring their authentic questions concerning the topic, which might have been triggered by their previous observations or materials prepared by the teachers. As a result, the teachers usually came up with several overarching questions that tended to cover students' interests and guided their following collaborative inquiry (although new questions would emerge as the Knowledge Building unfolded). Students were encouraged to record and synthesize content in the Knowledge Forum to make the ideas public and permanent for others to further build on. Students built explanations to respond to questions, evaluate the explanations, identify inconsistency between different theories and incoherence of theories, and rose above diverse theories to achieve new syntheses. This idea improvement process was usually supported by evidence from authoritative sources, field trips, experiments, and other investigative activities. In each class, the students and teachers usually engaged in offline Knowledge Building talks and online Knowledge Forum discourse, flexibility and seamlessly as they saw appropriate. The knowledge-building activities in each class lasted for about three months.

Data Collection and Analysis

The dataset used for this study consisted of 1101 online notes archived in the Knowledge Forum where students could post individual notes and build on existing notes in the discussion space. A build-on note, a contribution that links directly onto an existing note, is indicated by an arrow connecting the two notes on the screen (Figure 1).

This study adopted the natural and technical connection of notes when classifying notes into threads because students usually did not read all the notes to develop a comprehensive understanding when built on each other's notes in the Knowledge Forum. Our previous analysis (Zhu et al., 2017) suggested that students might ask semantically similar questions before, during, or after they read existing questions and responses in knowledge-building communities. To focus on how different kinds of questioning influence the sustainability of the Knowledge Forum discourse, we adopted the natural connection of notes and followed what students intuitively tend to do.

The ways of contributing framework were employed to analyze students' Knowledge Forum threads in each grade (Chuy et al., 2011). This framework was chosen because it offered a systematic inventory of ways of contributing that could shed light on how Knowledge Building discourse moves toward learning goals. As described above, this framework includes six main categories: questioning, theorizing, obtaining information, working with information, synthesizing and comparing, and supporting discussion. The questioning dimension includes three sub-categories: asking a factual question, asking a design question, and asking an explanatory question. However, in this study, we focused on factual and explanatory questions since there were fewer design questions.

We analyzed the sustainability and productiveness of threads according to the definitions of sustainability (i.e., length of a thread naturally connected in Knowledge Forum or an isolated note) and productiveness (i.e., if any note in a thread fell under the improving an explanation sub-category) as described in the literature review section. Table 1 shows the detailed descriptions of the dataset used. In sum, there were 342 threads contributed by the students in the five classes; there were a similar number of factual question threads (94) and non-question threads (89), while the number of explanatory question threads (159) was almost double.

Applying the ways of contributing scheme, two researchers coded all the notes and achieved an overall agreement rate of 95.52% across the five grades. To answer the first research question concerning the extent to which students could generate questions, we summarized the descriptive data of questions asked by each class in the Knowledge Forum. To respond to the second research question on the sustainability of threads led by different questions and non-questions, we conducted ANOVA analyses to examine if and how the length of the factual question, explanatory question, and non-question threads differ. Finally, to uncover the third question regarding the productiveness of questioning threads, we compared the frequency of productive threads led by different types of questions and non-questions. We further qualitatively analyzed three randomly selected productive threads led by an explanatory question, factual question, and non-question to showcase how different questions and non-questions guided the threads and influenced their productiveness.

Table 1

Description of the Dataset

Grades	Topics	Number of posts	Number of threads	Factual question threads	Explanatory question threads	Non-question threads
Grade 1	Water	298	81	12	55	14
Grade 2	Trees	117	41	2	23	16
Grade 3	Fungus	193	51	16	12	23
Grade 4	Rocks and minerals	262	93	33	37	23
Grade 5/6	Astronomy	231	76	31	32	13
Total		1101	342	94	159	89

Results

RQ1: Types of Student-Generated Questions

Table 2 shows that the students in each class could generate factual and explanatory questions. Grades 1, 2, and 4 asked more explanatory questions than factual ones, whereas Grades 3 and 5/6 students asked relatively more factual questions.

Table 2

The Descriptive Data of Questions in Each Class's Online Discourse

	Grade 1		Grade 2		Grade 3		Grade 4		Grade 5/6	
	M	SD	M	SD	M	SD	M	SD	M	SD
Factual question	0.90	1.21	0.09	0.29	0.86	2.05	1.67	1.35	3.00	2.19
Explanatory question	4.45	4.31	1.05	1.00	0.82	1.05	2.67	2.18	2.62	2.04

(means and standard deviation)

The distributions of thread length led by explanatory, factual, and non-questions of the five classes are shown in Figures 2, 3, and 4, respectively. Overall, there were more threads led by explanatory questions. The threads led by factual and explanatory questions were longer than those led by non-questions. Most threads led by non-questions ended within three notes, while some threads led by factual and explanatory questions went beyond ten notes.

Figure 2

The Length Distribution of Threads Led by Explanatory Questions in All Classes

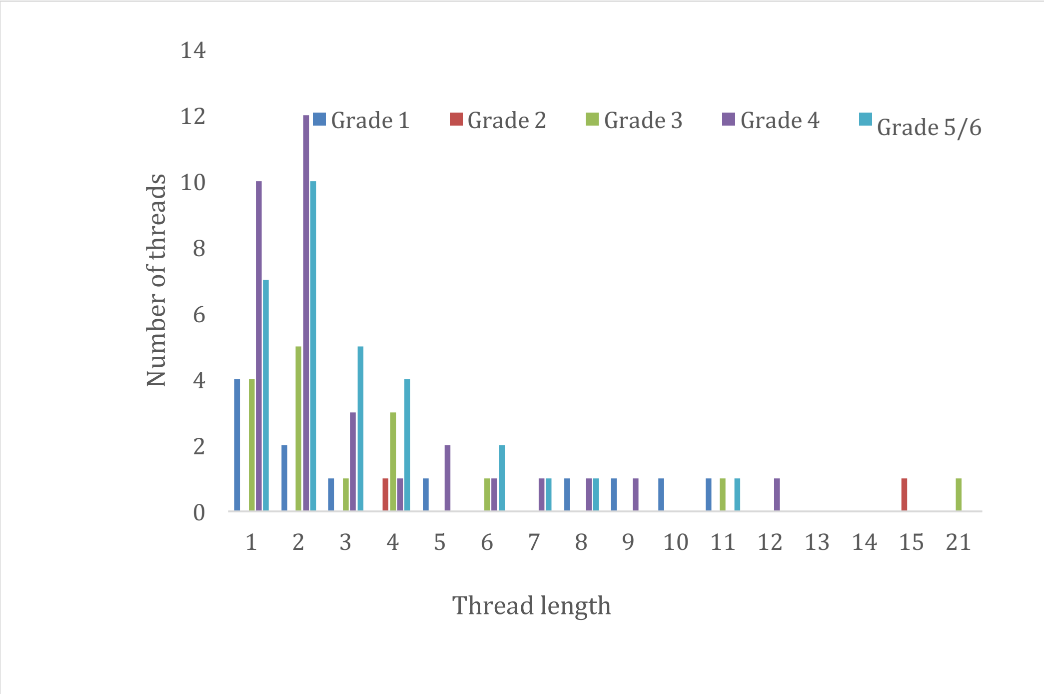


Figure 3

The Length Distribution of Threads Led by Factual Questions in All Classes

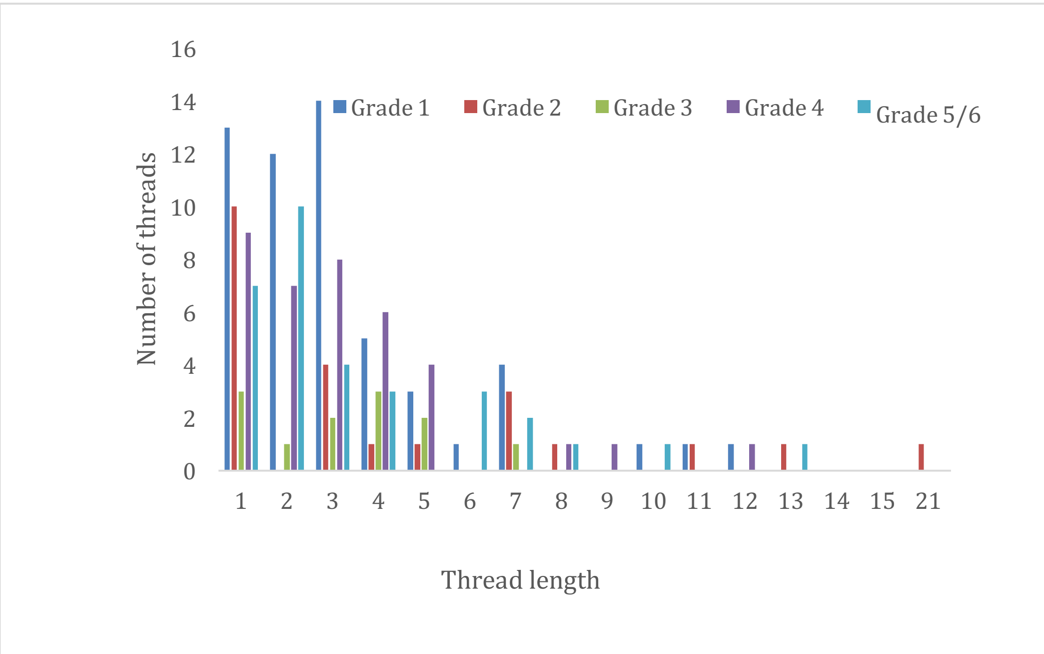
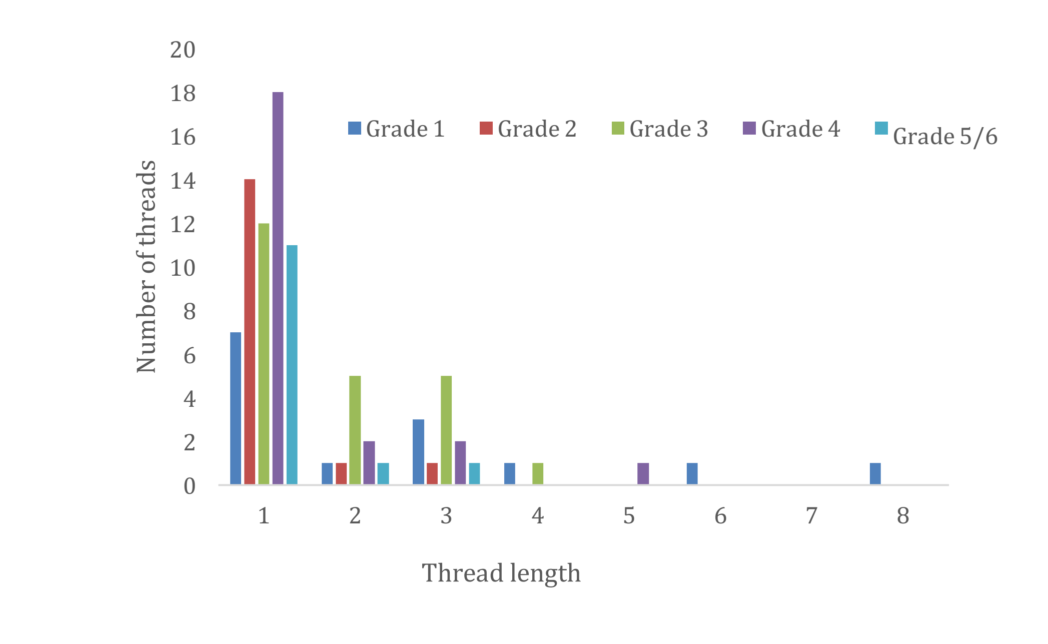


Figure 4

The Length Distribution of Threads Led by Non-Questions in All Classes



RQ2: Sustainability of Threads Led by Explanatory, Factual, and Non-Questions

Table 3 shows the descriptive data of the length of threads led by explanatory, factual, and non-questions and the ANOVA analysis results. The ANOVA analysis suggested that there was a significant difference between the length of explanatory, factual, and non-question threads ($F(2, 339) = 15.13$, $p<.001$). To further reveal which types of threads had significantly different lengths, we conducted Tukey's post-hoc comparisons. The results suggested that explanatory question threads were significantly longer than non-question threads ($Mean_{difference}=1.89$, $p<.001$). Similarly, the factual question threads were significantly longer than the non-question threads ($Mean_{difference}=1.93$, $p<.001$). However, there was no significant difference between the length of explanatory and factual question threads ($Mean_{difference}=.04$, $p=0.99$). An explanatory question and a factual question led to the two longest threads, respectively, both including 21 notes. The results suggested that compared to non-questions, actual questions resulted in more sustainable discourse.

Table 3

A Comparison of the Length of Explanatory, Factual, and Non-Question Threads

Type of threads	Mean	SD	ANOVA results
Explanatory question threads	3.52	3.01	$F(2, 339)= 15.13$, $p<.001$
Factual question threads	3.56	3.45	
Non-question threads	1.63	1.22	

RQ3: The Productivity of Threads Led by Explanatory, Factual, and Non-Questions

The number of productive threads led by explanatory, factual, and non-questions is shown in Table 4. In this table, the numbers in parentheses show the total number of threads in each category. It should be clarified that some threads started with notes that included factual and explanatory questions; those threads were counted as factual- and explanatory-question threads.

Table 4

Number of Productive Threads Led by Explanatory, Factual, and Non-Questions

	Grade					
	1	2	3	4	5/6	Total
Productive threads led by explanatory questions (total explanatory-question threads)	10 (55)	5 (23)	4 (12)	5 (37)	5 (32)	29
Productive threads led by factual questions (total factual-question threads)	3 (12)	0 (2)	2 (16)	4 (33)	5 (31)	14
Productive threads led by non-questions (total non-question threads)	1 (14)	1 (16)	2 (23)	2 (23)	1 (13)	7
Total number of productive threads (total threads)	13 (81)	6 (41)	6 (51)	11 (93)	9 (76)	45

As shown in Table 4, in each grade, more productive threads were initiated by explanatory questions. Indeed, compared to factual questions and non-questions, explanatory questions led to more productive threads. Also, compared to non-questions, factual questions resulted in more productive threads. For instance, in Grade 1, ten productive threads were led by explanatory questions; three productive threads were initiated by factual questions, while non-questions initiated only one productive thread. In total, there were 45 productive threads, and 29 of them started with explanatory questions, 14 began with factual questions, while non-questions led 7.

Three productive threads led by an explanatory question, a factual and a non-question, and a non-productive thread are provided in a qualitative analysis below. These three threads were randomly selected as representative of productive explanatory-question threads, productive factual-question threads, and non-question threads. These examples demonstrate how qualitative analyses using the ways of contributing coding scheme complemented the quantitative analyses: quantitative analyses could only show the sustainability of the discussion, while qualitative analyses could reveal whether those sustainable threads are productive or not. All students' names are pseudonyms, and grammar issues were corrected. At the end of each note, we included our ways of contributing code. Following each example, there is a discussion of the case to show the nuances of how the initiating notes influenced the development of the thread.

Example of a Productive Explanatory Question Thread

Jim: How are rocks made? (*Explanatory Question*)

Jessie: My theory is that rocks are made by magma drying and being compacted. (*Improving a Theory*)

Amy: My theory is that sand is in the sea starts to form in a number of years, and finally, it [a rock] forms. (*Improving a Theory*)

Charles: Some rocks are made by sand hardened sand. (*Supporting a Theory*)

Rachael: My theory is that wherever the rock is found is probably where it is made. (*Proposing a Theory*)

Sophia: The rock that I brought in is made out of pure hardened sand. (*Supporting a Theory*)

Kevin: There was a whole lot of volcano, and the ash came and lava, so the lava cooled, and you have your rock. (*Supporting a Theory*)

John: Rocks are made by minerals coming together over many millions of years. (*Supporting a Theory*)

The above thread started with an explanatory question proposed by Jim. Then Jessie and Amy raised their theories from different perspectives, one stating that rocks were made of magma, and one focusing on the time for rocks to form. These two theories were coded as "Improving a Theory" since they extended two existing theories in the community, which were "I think rocks are formed by minerals and thousands of years" and "I think diamonds are made by minerals compacting." Charles supported Amy's theory by stating that rocks were made of hardened sand. Rachael proposed a theory about where rocks were made. Sophia, Kevin, and John all supported previous theories. As two notes in this thread were coded as "improving a theory" notes, this thread was considered a productive thread. The notes built onto the explanatory question, coded as "improving a theory," "proposing a theory," and "supporting a theory," were all responses to the question.

Example of a Productive Factual Question Thread

Tom: What is a rock? (*Factual Question*)

Rachael: A rock is something that got hardened over time. It could be a sandstone, a lava rock, and many different kinds of rocks. (*Improving a Theory*)

Sophia: I think that some rocks just are hard they don't have to be compacted. (*Seeking an Alternative Theory*)

Jessie: My theory is that a rock is just a bunch of minerals and atoms all stuck together. (*Supporting a Theory*)

In this thread, Tom asked what a rock was. Rachael synthesized different existing theories, responded to the question of what rocks were, and listed various forms of rocks. Therefore, Rachael's theory was coded as "Improving a Theory." Sophia proposed an alternative theory by stating that rocks "don't have to be compacted," and Jessie supported previous theories. All the notes built onto the factual question were theories in response to the original question. Rachael's synthesis of previous theories made this thread productive.

Example of a Productive Non-Question Thread

John: You know when the earth was just being created? There were volcanoes simultaneously erupting, creating tons of lava. But when the giant rains came (creating the oceans), the top of the lava flood cooled, trapping the magma inside. (*Improving a theory*)

John proposed an advanced theory explaining how the crust was created. This note was a stand-alone note on Knowledge Forum. Before that, the students had discussed volcanoes formation, lava eruption, the rotation of the earth, and plate movement. Then Amy proposed, "Maybe some of the earth's crust built up." John's theory could be considered an improvement of the existing theories on volcanoes and crust because it synthesized these ideas and moved their theory of how the crust was created to a higher level.

Example of an Unproductive Thread

Tom: Some scientists think that the thing that exploded was the remains of an old universe. What if that universe had a life? The old life from the old life particles C. (*Seeking an Alternative Theory*)

Jacob: I think that's true. BUT what does C mean? (*Giving an Opinion, Factual-Seeking Question*)

This thread is an example of a non-productive thread that does not show evidence of knowledge advancement because rather than responding to the question "What if that universe had life," Jacob gave his opinion to Tom's statement and asked a factual-seeking question. This thread did not extend after.

Discussion

The results of this study confirmed that students as young as Grade 1 could generate a reasonable number of questions, sustain Knowledge Building discourse, and improve their intuitive theories to achieve productive discourse. The results suggest that question threads (either factual or explanatory) are significantly more sustainable and productive than non-question threads. The results support the literature on the importance of student questioning in science learning in general (Chin & Brown, 2000; Chin & Kayalvizhi, 2005; Chin & Osborne, 2008).

We found that both factual and explanatory question threads are significantly more sustainable than non-question threads. The reason may be that compared to non-questions, questions are more likely to remind students to explore the subject further to achieve a better understanding or to encourage their peers to take collective responsibility to respond to the questions. As progressive inquiry proceeds, new and more specific questions may emerge from the interaction between intuitive explanations, idea-deepening or elaborating questions, and scientific information from different students (Hakkarainen, 2003). Questions help a community to identify their current understanding, articulate the knowledge gap for further work, and convey a sense of seeking responses (Chin & Osborne, 2008). Furthermore, student-generated questions reflect students' authentic curiosity and their epistemic agency of where their collective inquiry should go (Scardamalia, 2002).

The results did not show a significant difference between the sustainability of factual question threads and explanatory question threads. The reason may be relevant to the types of questions students asked as Knowledge Building unfolded. That is, different questions might help propel the Knowledge Building discourse at different times. Miyake and Norman (1979) argued that "to ask a question, one must know enough to know what is not known" (p. 357), suggesting the importance of domain-specific knowledge for students to ask good questions. To test this argument, Scardamalia and Bereiter (1992) compared the nature of student-generated questions concerning the topics "fossil fuels" (students suggested they had little prior knowledge) and "endangered species" (students were more familiar with). They found although the number of student-generated questions did not differ in the two conditions, the students tended to ask more basic questions, e.g., "What are fossil fuels?" for the less familiar topic "fossil fuels." In contrast, they asked more wonderment questions, e.g., "How do scientists count a species so they know when it is endangered?" about the more familiar topic. In the current study, students asked more factual questions when they started their Knowledge Building on the science topics, and the questions helped sustain their inquiry; as the knowledge-building process unfolded as students became more familiar with the topics, they asked more explanatory questions. Further research should consider students' familiarity levels with their inquiry topics and the temporal dimension to better understand and support students in asking certain types of questions.

Across the five classes, explanatory questions resulted in more productive threads than factual questions and non-questions, and factual questions led to more productive threads than non-questions. This result is compatible with the existing literature, which suggests that compared to fact-seeking questions, explanation-seeking questions contribute more to advancing knowledge (Hakkarainen 2003; Zhang et al. 2007). Explanatory questions give students more opportunities to theorize the relationships and mechanisms between variables (Zhang et al. 2007), provide alternative theories, synthesize different theories, and improve their theories. Therefore, explanatory questions have a higher chance of leading to productive threads. Factual questions are more likely to be responded to with facts, terms, experiences, phenomena, or simple statements rather than theories (van Aalst, 2009; Zhang et al., 2007). Factual questions not embedded in genuine inquiry may result in fragmented pieces of knowledge, while explanatory questions have more potential to guide progressive inquiry (Hakkarainen, 2003). Lai and Law's (2013) study also suggested that threads with explanatory questions were more likely to lead to elaborated explanations.

The qualitative analysis of productive threads led by an explanatory question, a factual question, a non-question, and an unproductive thread suggested the importance of questioning and sustainable Knowledge Building discourse to productive threads. Hakkarainen's (2003) study indicated that progressive inquiry relied upon student-generated questions and peer interactions that encouraged students to pursue questions further through dynamic information, theorizing, comparing, and synthesizing. Furthermore, students tend to reduce an unfamiliar phenomenon, which may be represented by questions and suggests their knowledge gaps, to a familiar one (Hakkarainen, 2003) by addressing the questions through sustainable and progressive Knowledge Building discourse. However, not all questions resulted in productive threads since some of them may not have been addressed by students. This result is consistent with Lai and Law's (2013) study that concluded that one group of participants (i.e., Grade 10 students) were more capable of advancing their discourse through questioning, while the other group (i.e., Grade 6 students) were less capable of doing so. The authors mainly attributed such a difference to students' ages and further hypothesized that school context, student backgrounds, teachers, pedagogical contexts, and implementation procedures might have contributed to such a difference. Future research should consider these factors when examining students' Knowledge Building discourse.

Limitations

This study contributes to the body of research by examining how questioning engages students in sustainable and productive discourse. However, this study has several limitations.

First, the unit of analysis in this study included threads of discussions constructed by students on the Knowledge Forum. However, students might discuss semantically similar questions in different threads on Knowledge Forum, especially when they did not acquire a good awareness of the questions being discussed in their community. Semantically similar questions may affect the analysis of sustainability and productiveness.

Second, aligned with other studies (Hewitt, 2005; Hewitt & Teplovs, 1999), we defined a thread as an isolated note or a series of connected notes. The rationale for considering an isolated note as a thread is that even a single note contains an idea. Within the context of Knowledge Building, each idea is valuable and important and may spark new ideas in the community. Excluding single notes may result in ignoring valuable contributions. However, such a definition might be unconventional because CSCL researchers usually define a thread as a series of two or more connected notes. For future work, it would be reasonable to replicate the study with a more conventional definition of a thread and explore how the results may differ from the results shown in this paper.

Third, this study focused on Knowledge Forum notes but did not provide the details of each class's activity design (e.g., duration of inquiries, students' other interests, or the priority of Knowledge Forum discourse to student goals). In addition to questioning, the sustainability and productiveness of Knowledge Building discourse may be influenced by factors such as class norms, teacher guidance, and student interactions. However, although these factors might influence the Knowledge Building discourse, within each classroom, the influence might apply to all threads unless threads led by different questions were treated differently in class, which was not the case. These factors should be considered in future studies. Future researchers could also conduct design experiments to facilitate students in advancing their community knowledge through questioning, such as by highlighting unaddressed questions, selecting promising questions, connecting semantically similar questions, and developing specific epistemic scaffolds.

Conclusion

This study analyzed the sustainability and productivity of Knowledge Building discourse led by student-generated factual questions, explanatory questions, and non-questions in five primary classes. The results suggested that factual and explanatory question threads were significantly more sustainable than non-question threads. Moreover, productive threads were more likely to be led by explanatory questions than factual ones, while less likely by non-questions.

In knowledge-building communities, questions provide students with an inquiry and conceptual space where they can build on the questions with diverse theories, provide information, contribute critical evaluation and alternative theories, synthesize different and even opposite theories, and eventually improve their theories. Therefore, student-generated questions are an asset for a community to start and continue their Knowledge Building journey. Teachers and students often do not have problems working with student-generated questions at the beginning, however, as Knowledge Building inquiry unfolds, emergent questions generated by the students may not capture the community's attention in a massive and messy conceptual space. How to continuously support teachers and students to work on promising questions is a direction worth further study.

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References

Bereiter, C., Scardamalia, M., Cassells, C., & Hewitt, J. (1997). Postmodernism, knowledge building, and elementary science. *The Elementary School Journal, 97*(4), 329. https://doi.org/10.1086/461869

Black, P., Harrison, C., Lee, C., Marshall, B., & William, D. (2002). *Working inside the black box: Assessment for learning in the classroom*. *Phi Delta Kappan*, *86*(1), 8–21. https://doi.org/10.1177/003172170408600105

Campbell, J., & Stasser, G. (2006). The influence of time and task demonstrability on decision-making in computer-mediated and face-to-face groups. *Small Group Research*, *37*(3), 271-294. https://doi.org/10.1177/1046496406288976

Chen, B., Resendes, M., Chai, C. S., & Hong, H. Y. (2017). Two tales of time: Uncovering the significance of sequential patterns among contribution types in knowledge-building discourse. *Interactive Learning Environments*, *25*(2), 162-175. https://doi.org/10.1080/10494820.2016.1276081

Chen, B., & Zhang, J. (2016). Analytics for knowledge creation: Towards epistemic agency and design-mode thinking. *Journal of Learning Analytics*, *3*(2), 139-163. https://doi.org/10.18608/jla.2016.32.7

Chin, C., & Brown, D. E. (2000). Learning deeply in science: An analysis and reintegration of deep approaches in two case studies of grade 8 students. *Research in Science Education, 30*, 173–197. https://doi.org/10.1007/BF02461627

Chin, C., & Kayalvizhi, G. (2002). Posing problems for open investigations: What questions do pupils ask? *Research in Science & Technological Education, 20*(2), 269-287. https://doi.org/10.1080/0263514022000030499

Chin, C., & Kayalvizhi, G. (2005). What do pupils think of open science investigations? A study of Singaporean primary 6 pupils. *Educational Research, 47*(1), 107–126. https://doi.org/10.1080/0013188042000337596

Chin, C., & Osborne, J. (2008). Students' questions: A potential resource for teaching and learning science. *Studies in Science Education*, *44*(1), 1–39. https://doi.org/10.1080/03057260701828101

Chuy, M., Resendes, M., Tarchi, C., Chen, B., Scardamalia, M., & Bereiter, C. (2011). Ways of contributing to an explanation-seeking dialogue in science and history. *QWERTY - Interdisciplinary Journal of Technology, Culture and Education*, *6*(2), 242–260.

Cuccio-Schirripa, S., & Steiner, H. E. (2000). Enhancement and analysis of science question level for middle school students. *Journal of Research in Science Teaching, 37*, 210–224. https://doi.org/10.1002/(SICI)1098-2736(200002)37:2<210::AID-TEA7>3.0.CO;2-I

Fjermestad, J. (2004). An analysis of communication mode in group support systems research. *Decision Support Systems, 37*(2), 239-263. https://doi.org/10.1016/S0167-9236(03)00021-6

Graesser, A., & Olde, B. (2003). How does one know whether a person understands a device? The quality of the questions the person asks when the device breaks down. *Journal of Educational Psychology*, *95*, 524-536. https://doi.org/10.1037/0022-0663.95.3.524

Hakkarainen, K. (2003). Progressive inquiry in a computer- supported biology class. *Journal of Research in Science Teaching*, *40*(10), 1072-1088. https://doi.org/10.1002/tea.10121

Hewitt, J. (2005). Toward an understanding of how threads die in asynchronous computer conferences. *Journal of the Learning Sciences*, *14*(4), 567–589. https://doi.org/10.1207/s15327809jls1404_4

Hewitt, J., & Teplovs, C. (1999). An analysis of growth patterns in computer conferencing threads. In C. Hoadley & J. Roschelle (Eds.), *Proceedings of the Computer Support for Collaborative Learning* (CSCL) 1999 Conference (pp. 232–241). Stanford University Press. https://doi.org/10.3115/1150240.1150269

Hsu, C. C., & Wang, T. I. (2018). Applying game mechanics and student-generated questions to an online puzzle-based game learning system to promote algorithmic thinking skills. *Computers & Education, 121*, 73-88. https://doi.org/10.1016/j.compedu.2018.02.002

Khanlari, A., Resendes, M., Zhu, G., & Scardamalia, M. (2017). Productive knowledge building discourse through student-generated questions. *The Proceedings of the 12th International Conference on Computer Supported Collaborative Learning, 585-588.* Philadelphia, PA: International Society of the Learning Sciences.

Lai, M., & Law, N. (2013). Questioning and the quality of knowledge constructed in a CSCL context: a study on two grade-levels of students. *Instructional Science*, *41*(3), 597-620. https://doi.org/10.1007/s11251-012-9246-1

Miyake, N., & Norman, D. A. (1979). To ask a question, one must know enough to know what is not known. *Journal of Verbal Learning and Verbal Behaviour, 18*(3), 357–364. https://doi.org/10.1016/S0022-5371(79)90200-7

Osborne, R., & Wittrock, M. (1985). The generative learning model and its implications for science education. *Studies in Science Education, 12*, 59–87. https://doi.org/10.1080/03057268508559923

Pizzini, E. L., & Shepardson, D. P. (1991). Student questioning in the presence of the teacher during problem solving in science. *School Science and Mathematics, 91*(8), 348-52. https://doi.org/10.1111/j.1949-8594.1991.tb12118.x

Reeve, R., Messina, R., & Scardamalia, M. (2008). Wisdom in elementary school. In M. Ferrari, G. Potworowski. (Eds.) *Teaching for wisdom: Cross-cultural perspectives on fostering wisdom* (pp. 79–92). Springer. https://doi.org/10.1007/978-1-4020-6532-3_5

Resendes, M. (2014). *Enhancing knowledge building discourse in early primary education: Effects of formative feedback* [Doctoral dissertation, University of Toronto]. TSpace. https://tspace.library.utoronto.ca/handle/1807/65731

Resendes, M., & Dobbie, K. (2017). Knowledge Building gallery: Teaching for deep understanding and community knowledge creation (A collection of foundational KB practices and teacher innovations). Leading Student Achievement: Networks for Learning Project.

Resta, P., & Laferrière, T. (2007). Technology in support of collaborative learning. *Educational Psychology Review*, *19(*1), 65-83. https://doi.org/10.1007/s10648-007-9042-7

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67-98). Open Court.

Scardamalia, M. (2004). CSILE/Knowledge Forum®. *In Education and technology: An encyclopedia* (pp. 183–192). ABC-CLIO.

Scardamalia, M., & Bereiter, C. (1983). The development of evaluative, diagnostic, and remedial capabilities in children's composing. In M. Martlew (Ed.), *The psychology of written language: Developmental and educational perspectives* (pp. 67-95). John Wiley & Sons.

Scardamalia, M., & Bereiter, C. (1992). Text-based and knowledge-based questioning by children. *Cognition and Instruction*, *9,* 177-199. https://doi.org/10.1207/s1532690xci0903_1

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 97-115). Cambridge University Press.

Thagard, P. (2007). Coherence, truth and the development of scientific knowledge. *Philosophy of Science, 74*, 28–47. https://doi.org/10.1086/520941

van Aalst, J. (2009). Distinguishing knowledge-sharing, knowledge-construction, and knowledge-creation discourses. *International Journal of Computer-Supported Collaborative Learning*, *4*(3), 259-287. https://doi.org/10.1007/s11412-009-9069-5

Watts, M., Gould, G., & Alsop, S. (1997). Questions of understanding: Categorizing pupils' questions in science. *School Science Review, 79*(286), 57-63.

Yang, Y., van Aalst, J., Chan, C. K., & Tian, W. (2016). Reflective assessment in knowledge building by students with low academic achievement. *International Journal of Computer-Supported Collaborative Learning, 11*(3), 281-311. https://doi.org/10.1007/s11412-016-9239-1

Yu, F. Y. (2009). Scaffolding student-generated questions: Design and development of a customizable online learning system. *Computers in Human Behavior, 25*(5), 1129-1138. https://doi.org/10.1016/j.chb.2009.05.002

Zhang, J., Hong, H. Y., Scardamalia, M., Teo, C. L., & Morley, E. A. (2011). Sustaining knowledge building as a principle-based innovation at an elementary school. *The Journal of the Learning Sciences, 20*(2), 262-307. https://doi.org/10.1080/10508406.2011.528317

Zhang, J., Scardamalia, M., Lamon, M., Messina, R., & Reeve, R. (2007). Socio-cognitive dynamics of knowledge building in the work of 9- and 10-year-olds. *Educational Technology Research and Development, 55*, 117-145. https://doi.org/10.1007/s11423-006-9019-0

Zhang, J., Tao, D., Chen, M. H., Sun, Y., Judson, D., & Naqvi, S. (2018). Co-organizing the collective journey of inquiry with idea thread mapper. *Journal of the Learning Sciences*, *27*(3), 390-430. https://doi.org/10.1080/10508406.2018.1444992

Zhu, G., & Kim, M. S. (2017, June). *A review of assessment tools of Knowledge Building towards the norm of embedded and transformative assessment*. Paper presented in Knowledge Building Summer Institute 2017, Philadelphia, PA.

Zhu, G., Resendes, M., Khanlari, A., Scardamalia, M., & Wu, Y. T. (2017, June). Asking semantically similar questions in knowledge building communities: patterns and effects. *The Proceedings of the 12th International Conference on Computer Supported Collaborative Learning (pp. 875-876)*. Philadelphia, PA: International Society of the Learning Sciences.

Zhu, G., Teo, C. L., Khanlari, A, & Mohd, S. B. (2018, August). *The use of Knowledge Building scaffolds by grade 7 students*. Paper presented in Knowledge Building Summer Institute 2018. Toronto, ON.

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Digital Competence in Primary Education and the Limits of 1:1 Computing

La compétence numérique à l'école primaire et les limites de l'informatique 1:1

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Abstract

Almost a decade after the massive incorporation of technology into schools in Galicia, Spain based on 1:1 computing programs, where teachers and students have access to laptop computers, this study explored the effects of technology on the lives of children in situations of socio-cultural and economic exclusion. Three case studies were selected from two research projects. Each case study representing three individuals. These studies were analyzed through an ethnographic approach using in-depth interviews and participant observation. The constant comparative method was used, supported by ATLAS.ti 7 qualitative analysis software. The 1:1 policies excluded the family context and the development of digital competence was heavily dependent on the opportunities provided at school. The results indicated that these policies did not reduce inequality because advanced learning experiences with information and communication technology were not provided at school.

Keywords: Digital competence; Digital literacy; Primary education; Exclusion; 1:1 computing

Résumé

Près d'une décennie après l'incorporation massive de la technologie dans les écoles de Galice, en Espagne, basée sur des programmes informatiques individualisés (1:1), où les enseignants et les élèves ont accès à des ordinateurs portables, cette étude a exploré les effets de la technologie sur la vie des enfants en situation d'exclusion socioculturelle et économique. Trois études de cas ont été sélectionnées à partir de deux projets de recherche. Chaque étude de cas représente trois individus. Ces études ont été analysées par une approche ethnographique utilisant des entretiens approfondis et l'observation des participants. La méthode comparative constante a été utilisée, soutenue par le logiciel d'analyse qualitative ATLAS.ti 7. Les politiques individualisés (1:1) excluaient le contexte familial et le développement de la compétence numérique dépendait fortement des possibilités offertes à l'école. Les résultats indiquent que ces politiques n'ont pas réduit les inégalités car les expériences d'apprentissage avancées avec les technologies de l'information et de la communication n'étaient pas proposées à l'école.

Mots-clés : Compétence numérique ; Alphabétisation numérique ; Enseignement primaire ; Exclusion ; Informatique individualisée 1:1

Introduction

Digital technologies have become essential resources in the digital era. In this context, there is a clear and urgent need to train citizens for a digital environment. This means learning to consume and to produce media message, creating and expressing yourself with digital technology, and knowing how to act in the digital sphere.

In recent years, the European Union (EU) has advanced in defining digital literacy as an element for the convergence of different literacies, such as information technology literacy, information literacy, technological literacy, media literacy, and visual literacy (Martin, 2006). Some of these, including technological literacy (Martin, 2008; Martin & Grudziecki, 2006) have a long tradition, which has been reinforced in the current digital context with supportive elements that provide a current and valid frame of reference (Breuch, 2002). European Union educational systems require digital competency training for students. Progress has been made to concisely define digital competence via frameworks such as The Digital Competence Framework for Citizenship (Ferrari, 2013) and its updated version the DigComp 2.2 (Vuorikari et al., 2022); a specific version of digital competence for educational environments called DigcompEdu (Redecker & Punie, 2017); and another version specially designed for organizations called DigCompOrg (Kampylis et al., 2015), which has generated the Self-reflection on Effective Learning by Fostering the use of Innovative Educational (SELFIE) technologies project for the evaluation of educational institutions. This project has yielded specific data (Castaño-Muñoz et al., 2021). Other frameworks fall under the umbrella of DigComp, including the Life Comp (Sala et al., 2020) which focused on key competences for lifelong learning. The use of competence concepts, specifically digital competence, has provided a common language and structure for EU education systems. This framework has been explicitly included in the latest school regulations for primary education in Spain (Organic Law 2/2020 of Education, 2020). Following the Council Recommendation of 22 May 2018 on key competences for lifelong learning, an updated version of the recommendation of the European Parliament and of the Council of 18 December 2006 (European Commission, 2006), digital competence was defined as:

> the confident and critical use of Information Society Technology (IST) for work, leisure, and communication. It is underpinned by basic skills in ICT: the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet. (European Commission, 2018a, p. 6)

Learning digital competence has become fundamental for 21st century citizens. It is vital for full, active, democratic, free, responsible, and critical participation in society. From a social justice perspective and because of their transformative power (Fullan, 2001), schools have become privileged places for the integration of digital media (Selwyn, 2011). This knowledge has become an indispensable element of social inclusion for students and their families, and it is for this reason that 1:1 computing programs were implemented for the development of digital competence.

The 1:1 Model in Galicia (Spain): The Abalar and E-Dixgal Project

The Abalar Project, which began in 2010, promoted 1:1 policies in Galicia, Spain focusing on four issues: 1) equipment and infrastructures, ensuring the generation of digital educational centres; 2) digital educational contents and resources with new educational models and improvement of educational practices collaboratively with teaching staff; 3) promotion of digital culture by both teachers and families; and 4) creation of collaborative digital spaces for teachers, students, and families (Xunta de Galicia, 2010). In order to promote these changes, teachers with special roles were selected to invigorate educational and methodological innovation in educational centres, implementing a training proposal for teachers at the coordinator level in educational centres and of a pedagogical nature for the other participating teachers (AMTEGA, 2013). It prioritized the allocation of teachers to schools based on teacher's interest (Order of June 28, 2010).

The Abalar Project began by distributing one computer per student in the participating classrooms as follows: Grade 5 and 6 of primary school and the first and second year of compulsory secondary education at selected schools (1000 schools participating but only 514 schools received the first computers installment). Unlike the One-Laptop-Per-Child project in Galicia, which was clearly an inspiration in the pursuit of equity, inclusion, and equality, laptops were only distributed in those schools participating in the project and their use was allowed only at the school. From the outset, this was problematic in terms of family involvement in the 1:1 model, a fundamental dimension that, as research shows, has been neglected (San Martín et al., 2014).

In 2014, a second phase was launched, the E-DIXGAL Project, which focused on the implementation of digital textbooks in the classrooms that were already part of the Abalar Project. The change permitted working with the equipment at home, which provided continuity for what was done in the classrooms (Valiente, 2011). This second phase consisted of 267 of the 514 schools in the Abalar Project. Thus, there were three different levels in Galician public schools: those that were not included in 1:1 policies, those in the Abalar Project, and those in the Abalar-E-DIXGAL program (Fraga-Varela & Alonso-Fereiro, 2016).

Research on the Abalar and E-DIXGAL projects showed that they mainly focused on the provision of equipment, without concrete actions or proposals for contributing to changes in teaching practices and methodologies (Area, 2011; Dussel, 2017; Fraga-Varela & Alonso-Ferreiro, 2016; Selwyn & Facer, 2013). A lack of administrative support characterized both projects (Alonso-Ferreiro & Gewerc, 2015). Some studies pointed to factors such as the lack of specific training on issues associated with digital competence in curricula, in contrast to traditional knowledge areas (Howard et al., 2015) or the fact that standardized external evaluation tests fail to include these digital competencies because value is placed on other skills (Blau et al., 2016). Interestingly, a study that evaluated digital competence, and not self-perception, confirmed the low levels of development of this competence in primary education (Fraga-Varela et al., 2020), which was clearly in line with previous studies (Aesaert et al., 2015).

Digital Citizenship: Digital Competence as a Path to e-Inclusion

Approaching the study of digital competence as a matter of inclusion requires doing so from the perspective of the digital divide, which views literacy as a process that aims to achieve active democracy, participation, and citizenship (Gewerc & Armando, 2016), stressing access and participation gaps, and questioning digital nativity. Van Dijk & van Deursen (2014) pointed to digital skills as the key to living in the information society and the differences in the development of these skills as one of the main causes of current social gaps.

Digital competence is transformative and disruptive in the current era (Selwyn, 2014), including aspects of exclusion and inequality. It goes beyond merely technological issues (van Dijk, 2005). As a result, the EU DigComp Framework considered this competence to be key for inclusion in the digital society (Ferrari, 2013; Vuorikari et al., 2022). The project established five areas with 21 competencies (Table 1) and 8 levels of proficiency. In addition, it highlighted the importance of digital competence for everyday life and as an element of inclusion, warning that its absence can exacerbate the condition of disadvantaged people and further exclude them socially.

Proposals for 1:1 computing helped reduce the access barrier but second-order barriers, like teachers' pedagogical beliefs (Ertmer, 2005), involving the use of digital resources were spreading and deepening (van Dijk, 2005). This was mainly due to differences in economic, cultural, and social opportunities as well as family variables (Selwyn & Facer, 2007). In this context, promoting digital competence in schools is essential (Selwyn, 2004; van Dijk, 2005; van Dijk & van Deursen, 2014), without losing sight of the family as a privileged educational setting (Bourdieu, 2008).

Digital competence emerges as one of the key elements of schooling in the 21st century (Selwyn & Husen, 2010). In this regard, the 2021 Digital Economy and Society Index (DESI) data indicated that 44% of the population in the EU lacked basic digital skills, with an improvement of only 1% in two years (European Commission, 2021). The recent COVID-19 lockdown exacerbated the inequalities resulting from the lack of available equipment, the lack of family and caregiver support, and unequal levels of digital competence, among others, which remain low among students excluding them from distance learning without the support of their families (Carretero et al., 2021).

With respect to exclusion, cultural capital is an important aspect of scholastic success (Bourdieu, 2008). In this sense, Aesaert et al. (2015) indicated several factors within the educational context as fundamental for the development of digital competence; however, they noted the greater impact of factors having to do with personal and family aspects, unrelated to the school setting. These authors mentioned issues such as experiences with information and communication technology (ICT), their use outside of school, availability at home, parental support, and attitude towards these technologies as conditioning factors for developing digital competence. Moreover, a variety of researchers maintain the existence of a relation between socioeconomic status and the opportunity to develop digital competence (Aesaert et al., 2015; Claro et al., 2012; Selwyn & Husen, 2010; Vekiri, 2010; Zhong, 2011).

Table 1

DigComp 2.2 Areas and Competences (Vuorikari et al., 2022)

Competence areas	**Competencies**
Information and data literacy	1. Browsing, searching, and filtering data, information, and digital content 2. Evaluating data, information, and digital content 3. Managing data, information, and digital content
Communication and collaboration	1. Interacting through digital technologies 2. Sharing through digital technologies 3. Engaging in citizenship through digital technologies 4. Collaborating through digital technologies 5. Netiquette 6. Managing digital identity
Digital content creation	1. Developing digital content 2. Integrating and re-elaborating digital content 3. Copyright and licenses 4. Programming
Safety	1. Protecting devices 2. Protecting personal data and privacy 3. Protecting health and well-being 4. Protecting the environment
Problem solving	1. Solving technical problems 2. Identifying needs and technological responses 3. Creatively using digital technologies 4. Identifying digital competence gaps

As recently as 2020, the EU boosted policies with its Digital Education Action Plan (2021-2027) at the core of which are the needs exposed by the COVID-19 by establishing two basic principles (European Commission, 2020a): fostering the development of a high-performing digital education ecosystem (strategic priority 1) and enhancing digital skills and competences for the digital transformation (strategic priority 2). Additionally, the Skills Agenda for Europe in July 2020 aimed at helping individuals and companies develop better skills (European Commission, 2020b). This strategy is part of a set of 12 flagship actions that seek to reach and train 60% of the adult population by 2030.

In this regard, acknowledgement is made of the need to update the Digital Competence Framework in 2022 with DigComp 2.2 (Vuorikari et al., 2022). This work contributed to a common approach to digital skills, digital upskilling, and the assessment and framing of policies.

The massive introduction of technological equipment into schools under the 1:1 model has led to an interest in understanding how this type of school policy affects the development of digital competence. There is concern for children from disadvantaged backgrounds who have little opportunity outside of the school institution. This study answers these questions: What is currently happening at school, after almost a decade of massive integration of digital technologies under 1:1 computing programs? How has this contributed to the development of digital competency among young people lacking opportunities outside the educational context?

Methodology

To answer the research questions, we analyzed three cases of primary age students from two recent studies carried out within the Stellae Research Group of the University of Santiago de Compostela. Both studies used a methodological design focusing on multiple-case studies (Yin, 2017) with an ethnographic perspective (Simons, 2009) involving primary school students enrolled in 1:1 computing programs. This approach coincided with what Coller (2005) called a multiple analytical case study, which provided a better understanding of the problem from multi-sited perspective (Rockwell, 2008). In terms of access to students, a sampling of maximum theoretical return (Stake, 1995) was used for the selection of cases. The following pseudonyms were used for anonymity: Arthur, Benjamin, and Jack (Table 2).

Table 2

Characteristics of the Subjects that Make up the Sample

Case	Grade	Family situation	Limitations	Area
Arthur	Grade 5	Parents are separated	Repeats a grade	Semi-rural
		A younger sister	3 hours/week with therapeutic pedagogy teacher	Family home
		Retired grandfather, only source of income		
Benjamin	Grade 6	Lives with his grandparents and his sisters	Curricular adaptation	Semi-urban
		Grandmother has some cleaning jobs, the only source of income		

Case	Grade	Family situation	Limitations	Area
Jack	Grade 6	Only child Unemployed father, gamer Mother has a cleaning job, the only source of income	Repeated a grade ADHD	Urban

Both reference studies used in-depth interviews with key informants and participant observation for data collection (Table 3). The information was registered in field diaries, video, and audio recordings.

Table 3

Data Collection Techniques in Each Case

	In-depth Interviews	Classroom Observation
Arthur	1 interview with his tutor	Observation for three months
Benjamin	3 interviews with Benjamin 2 interviews with his grandmother 1 interview with his tutor	3 visits to the centre
Jack	3 interviews with Jack 2 interviews with his mother 1 interview with his tutor	3 visits to the centre

The children, their tutors, and their families were interviewed. The resulting data were analyzed with the constant comparative method (Glaser & Strauss, 1967) by means of an inductive and sequential categorization (Muñoz & Sahagún, 2010). Field observation notes and interviews were transcribed for analysis using ATLAS.ti software following the proposal by Miles and Huberman (1994), which indicates data reduction, data display, drawing, and verifying conclusions. The first two steps involved coding and documenting, followed later by abstracting and comparing. We looked for regularities and concept development by applying alternative strategies during the inductive and deductive data analysis. Subsequently, interpretative hypotheses were made.

Citation codes were used for direct quotes from interview transcripts and field notes. The codes referred to pseudonyms (Ja = Jack, Ar = Arthur, and Be = Benjamin). Also indicated were the data collection source (I = interview and O = Observation), the person interviewed (T = Teacher, P = Principal, F = Father, M = Mother and G = Grandmother), and the interview/observation number. Lastly, the transcript paragraph number was added to the ATLAS.ti file.

Results

Although Jack, Benjamin, and Arthur had their own peculiarities, there was a common denominator indicating that they could be analyzed jointly. All three cases involved boys enrolled in compulsory primary education in Spain consisting of six grades for ages 6-12. Our subjects were at the end of this education stage. Jack and Benjamin were in Grade 6 and Arthur was in Grade 5. All were at schools with extensive implementation of technological equipment under the 1:1 model. All three cases also presented clear socioeconomic difficulties within the family and an evident risk of exclusion.

Specific factors informed the peculiarities of each case. Jack was exactly 12 years old and had repeated Grade 4. In general, he struggled with the core subjects such as mathematics and Spanish. He was diagnosed with attention deficit hyperactivity disorder (ADHD) and had been prescribed daily medication since the age of 9. According to his family, in addition to these difficulties, the child had low self-esteem and a high degree of immaturity "he is very childish and very immature" (Ja_I_M2_143). However, Jack's attitude problem was seen differently from the school's standpoint, highlighting his "*bad boy*" role, as reported by his tutor: "[teacher talking like Jack] well I don't work, I dedicate myself to other things, ok? Well, I tease and laugh at my classmates, because I'm going to be superior…" (Ja_I_T1_30). As emerged from his family's comments, this attitude was a source of conflict in his social relationships with peers because it led to restless attitudes. His mother indicated, "I don't like him to go to anyone's house because Jack is a child that you have to ... how can I say this... he needs supervision. He is a very restless child" (Ja_I_M2_177-179).

Benjamin was also in Grade 6, having previously stayed back a year. After failing to get back on track, a curricular adaptation was applied, which he passed. This approach allows curricular standards to be lowered for a student usually after repeating a course. The activation of a curricular adaptation requires the teacher to completely re-plan the course to adapt to the student's real learning potential. In other words, it implies a distancing from the objectives set for the other members of the class. But Benjamin's situation did not seem to be under control because he presented unusual difficulties for a student of his age, e.g., his writing, drawings, syntax, and vocabulary continued to be below grade level expectations. Speaking with the school principal, the particularity of the case was confirmed: "he failed languages, yes" (Be_I_T1_655). This contrasted with Benjamin's academic record, which presented relatively normal grades except for languages, and the deactivation of the curricular adaptation. The reported academic normality did not align with what was observed.

Arthur was in Grade 5. His academic situation was not good either. The school had already decided months before the end of the academic year to hold him back. This decision was conditioned by the student's limited potential for dealing with the next grade successfully. The decision to hold Arthur back revealed how difficult his situation was. This also explained the special support he received via three class sessions per week with specialized teaching staff (Ar_O_Ar3_64). These measures are only activated in response to learning problems and the need for remedial support.

A Complex Scenario: Economic Difficulty and Family Dysfunction

Both Benjamin and Arthur had highly dysfunctional family settings. His mother was not in Galicia at the time and his father was abroad. Benjamin and his two sisters were fostered by their maternal grandparents and supervised by social services. However, the situation was not easy, and his own grandmother made that clear at school. The situation was reflected by the testimony she gave to the tutor. She explained that the situation was difficult because the pay was insufficient: "for the money they give me" (Be_I_G1_769). The problem was very complicated. He had already been in a juvenile centre, a foster family, and his grandparents finally assumed the responsibility. His teacher made us aware of this situation: "if he had a normal life, if he had... a normal development since childhood" (Be_I_T1_679) meaning that if he had a stable home environment, he might have been in a better academic situation. Benjamin's grandmother lived on the outskirts, still within the boundaries of the city but in a semi-rural environment. The family got by, thanks to a supplementary income involving the care of some animals. The financial situation and the location of his home made it difficult for the child to participate in extracurricular activities: "because it costs a lot of money" (Be_I_Be1_623). Money was scarce and his grandmother, the only one with a salary, held down several cleaning jobs simultaneously to maintain the household.

Arthur lived in an extended family where several generations shared the same space: parents, grandparents, and a younger sister, who was in Grade 1 of primary school. His parents were divorced, but because of their financial difficulties, they lived in different parts of the same house. All the members of the family were unemployed and had little schooling. The main source of income was the grandfather's pension. The father received an unemployment subsidy. The file indicated that "Arthur's custody is held by his father, while his sister's is held by their mother" (Ar_O_D1_28). The village where they resided was not far from the urban centre and characterized by the coexistence of a traditional population, dedicated to agriculture and livestock, and an urban population, inhabiting the newer buildings. This situation involved tension and conflict, especially due to the differences between the long-time local families and those from a more urban origin and higher socioeconomic status.

Lastly, Jack lived in the city in a house that belonged to his maternal grandmother. His parents were approximately 30 years old. They had him at the age of 17, which meant early parenthood. His father was unemployed, and his mother worked as a cleaner three days a week. Both had little schooling. His mother seemed to be the head of the family because she contributed the only salary, managed the schooling, looked after the children, and dealt with the difficulties resulting from the ADHD.

These cases shared the following common elements: very low parental education levels and financial difficulties due to unemployment or minimal wages. Even in a developed country like Spain, these situations undoubtedly involve very high vulnerability and risk of exclusion, which exemplifies the national child poverty rate of over 30% (European Commission, 2018b). Rather than abject poverty and high levels of material deprivation, it is more a risk relating to financial and social limitations as well as lack of opportunities (González-Bueno, 2014).

Schools at a Crossroads? When Availability Does Not Guarantee the Use of Technological Equipment

Jack, Benjamin, and Arthur attended schools participating in the Abalar project. Their classrooms had a laptop for each child with Internet access and various educational resources. Nevertheless, the potential these devices offer for digital competence, requires a revision of school planning designs. Participation in the program implies acceptance by the school faculty.

For whatever reason, very limited use of the 1:1 equipment was observed. Arthur used computers similarly to textbooks, which meant putting the focus on the search for information and interactive exercises. The ICT coordinator defended this approach, "so children have to learn to use a book, to extract from the book and, in addition, to know how to search for information on the Internet" (Ar_I_C-TIC_29). Arthur's teacher, with more than 20 years of experience, emphasized the importance of searching, but her language revealed a lack of training in search strategies, placing the focus on avoiding risk, "...by adding more details of what you want to look for, but then I started directing him myself to specific pages." (Ar_I_T1_299). To illustrate Arthur's relationship with technology, a critical incident happened in a classroom session dedicated to searching on the Internet about an author. During his search, the child found a page with sketches by the author, which included a collection of naked women. While the rest of his classmates avoided this type of content, he focused his attention there, until a companion gave him away "Arthur is watching naked girls!" (Ar_O_D20_23); fulfilling one of the fears the tutor had regarding the risks of free Internet search.

The computer was used, therefore, to search for information or at best to make a presentation in Impress, a program in the OpenOffice suite. Arthur spent little time on this, as the class usually did this type of work when Arthur was out of the room for remedial education sessions. His difficulties were not limited to working with the computer:

> Arthur has difficulty...simply knowing how to...open an Impress, get into his folder, and save something. And the others are different, the others... more or less get by, but this child in particular... the difficulties he has in other areas are also there. (Ar_I_T1_317)

However, the school went no further, because the support that Arthur needed in terms of individualized learning was also needed for digital competence. Nevertheless, nothing indicated that the school was going to resolve the situation.

The search for information was a common pattern in the three cases. A similar situation also occurred with Benjamin and Jack. They never got past that point. The equipment was available, but the classroom activities did not make it possible to take advantage of all its potential. Benjamin's teacher was asked to act as a mediator in a conflict with families in a previous tutoring session. The teacher was given specific indications regarding a teaching style recognizable and understandable to families. Everything revolved around the textbook, which functioned as a type of peace agreement between families and the school: "what they want is a notebook where they see that work is being done, but if on the other hand you work a different way, then ...what might they be doing?" (Be_I_T1_861). This implies a partial use of resources, an exploration of the first dimension of digital competence in the form of information search that complements the tasks proposed by the textbook, and a situation that we recognized from Arthur's experience. Information was "sometimes searched for on their own because I tell them that they have to learn to search... Ok, I'll look for it" (Be_I_T1_1099). This situation was even recognized by the school administration "...finding information? Anything that's not in Wikipedia doesn't exist "(Be_I_P1_611). Not very different from Jack. The use of technology in this case was equivalent to using the textbook as a reference.

The search for information was a key aspect and everything seemed to indicate that Jack was skillful in this area: "because if he is on the team, no matter who the other members of the team are, he is the one who is going to search for information" (Ja_I_T1_789). Jack's case involved an interim teacher without a permanent position, but who had had a very long career since "this is my twenty-eighth or twenty-ninth year at school" (Ja_I_T1_625). In any case, hardly any area other than searching was explored. As the mother told us, "some exercises in the book do ask them to find information about a writer or something on the Internet and they have to look for it themselves" (Ja_I_M1_312). This is the case of the sonnet: "now you are going to use Abalar's computers and search in Google as a team. You are going to search for a sonnet, ok? A poem that is a sonnet" (Ja_I_T1_177). The child recognized that nothing other than this format is done: "Interviewer: Did they teach you at school about...well...how to use technology? Jack: No." (Ja_I_Ja3_340-341). The children had conflicting feelings. On the one hand, they saw themselves as controlling the situation "I am the one who knows the most [in the class]" (Ja_I_Ja1_876), however their limitations were also evident, "not much about the computer because I never use it "(Ja_I_Ja2_799).

Considering the five dimensions in the DigComp (Vuorikari et al., 2022) the results reveal the scarcity of opportunities provided at school because only the most instrumental aspects of information and data literacy were addressed. The remaining dimensions were left out of consideration. There were some specific instances of digital content creation, such as Arthur's use of Impress, but safety or problem solving were not addressed. Neither did communication and collaboration appear. This situation deserves attention considering the challenge that managing all the technologies children encounter in their daily lives in and outside the school entails.

Discussion and Conclusions

The aim of this study focused on looking into the development of the digital competence in schools in Galicia, Spain based on using the 1:1 computing program model. The study of these three cases revealed low levels of digital competence. School work mainly encouraged information and data literacy to the detriment of the other competence dimensions (Vuorikari et al., 2022). The dimensions that were not promoted at school were strongly dependent on the cultural capital of the family (Bourdieu, 1990), which was very limited in these three cases because the parents had limited schooling and resources. Schools have no direct influence over certain aspects but they can help to compensate. As Erstad (2010) states, digital competence is related to overall results at school and parents' educational background. These children's parents were unemployed and had only a basic education, and therefore the educational institution had the greatest responsibility.

Our findings illustrate the influence of socio-family factors on the development of digital competence, as several authors have previously highlighted (Aesaert et al., 2015; Selwyn & Facer, 2007; van Dijk, 2005). Furthermore, there is a need to reconsider this situation from perspectives such as cultural capital (Bourdieu, 1990). Regarding the curricular need to address digital competence, the participating teachers undervalued it. In this context, the implementation of a 1:1 computing program could enrich more intensively all the dimensions of digital competence. This finding confirms previous research (Area & Sanabria, 2014).

Helping to understand the role that schools play in this situation is important. Public administrations have promoted policies that necessarily require the provision of equipment and digital infrastructure. They have not neglected the contribution to new pedagogical models or the improvement of educational practices in their educational objectives when promoting 1:1 programs (AMTEGA, 2013; Xunta de Galicia, 2010). This objective is still present in the reality of current policies (European Commission, 2018a, 2021). However, in line with other studies, we see that difficulties persist (Carretero et al., 2021). Other studies such as SELFIE (Castaño-Muñoz et al., 2021) show how this is perceived by the school administration, teachers, and students, but a more detailed analysis of the day-to-day reality of the classroom is needed. This situation emphasizes the need to revise school curricula as Howard et al. (2015) point out. Regardless of material and organizational conditions, teachers and educational centres require specific guidelines regarding what it is expected of their work in relation to all dimensions of digital competence to promote further development in contrast with current data (Fraga-Varela et al., 2020). While our objective is clear, we need first to revise and enrich the work that is being done at schools as well as their curriculum and the applicable legislation. Everything suggests that this type of learning has not been prioritized nor has it been structured or organized properly to effectively integrate into the classroom.

The implications of all these elements need to be analyzed in the teaching pedagogical patterns. Teaching with the same materials and the same teacher planning design, even with the extensive availability of technology under the 1:1 model, does not lead to change or transformation, but instead reproduces the same results (Salinas-Amescua, 2007). The dependence on textbooks and their structure prevents the exploration of digital environments and brings to light the enormous challenge of working with them (Sadera & Parrish, 2018). It also reveals a lack of teacher knowledge regarding technology, which is necessary for taking advantage of its potential (Öqvist & Högström, 2018). This is evident in all three cases. Arthur, Benjamin, and Jack presented no change or learning in the school environment to allow improvement in the appropriation of the available technology. These cases force us to question the potential of digital technologies for overcoming social and cultural inequalities and the true role of schools is this day and age, seeing as technological equipment in and of itself produces no change at all (Cuban, 2015). The need is also clear for families and schools to work in sync to bridge the gaps between them.

References

Aesaert, K., van Braak, J., van Nijlen, D., & Vanderlinde, R. (2015). Primary school pupils' ICT competences: Extensive model and scale development. *Computers & Education*, *81*, 326-344. https://doi.org/10.1016/j.compedu.2014.10.021

Alonso-Ferreiro, A., & Gewerc, A. (2015). ICT teachers' lifelong training in Galicia: Do we always trip over the same stone? *Innovación educativa*, *25*, Art. 25. https://doi.org/10.15304/ie.25.2757

Area, M. (2011). The effects of the Model 1:1 in the educational change in schools. Evidence and challenges for the Ibero-american policies. *Revista Iberoamericana de educación*, *56*, 49-74.

Area, M., & Sanabria, A. L. (2014). Opinions, expectations and evaluations of teachers participating in the School Program 2.0 in Spain. *Educar, 50*(1), 15-39. https://raco.cat/index.php/Educar/article/view/287066

Axencia Para A Modernización Tecnoloxia De Galicia (AMTEGA) Agency for the Technological Modernization of Galicia. (2013). *Free Software Action Plan Year 2013 Free Software Coordination Office.* https://amtega.xunta.gal/es/documento/plan-de-software-libre-2013

Blau, I., Peled, Y., & Nusan, A. (2016). Technological, pedagogical and content knowledge in one-to-one classroom: Teachers developing "digital wisdom". *Interactive Learning Environments*, *24*(6), 1215-1230. https://doi.org/10.1080/10494820.2014.978792

Bourdieu, P. (1990). *In other words: Essays towards a reflexive sociology*. Stanford University Press.

Bourdieu, P. (2008). *Cultural capital, school and social space.* Siglo XXI Editores.

Breuch, L. A. K. (2002) Thinking critically about technological literacy: Developing a framework to guide computer pedagogy in technical communication, *Technical Communication Quarterly, 11*(3), 267-288, https://doi.org/10.1207/s15427625tcq1103_3

Carretero, S., Napierała, J., Bessios, A., Mägi, E., Pugacewicz, A., Ranieri, M., Triquet, K., Lombaerts, K., Robledo-Bottcher, N., Montanari, M., & Gonzalez-Vazquez, I. (2021). *What did we learn from schooling practices during the COVID-19 lockdown?: Insights from five EU countries*. Publications Office of the European Union. https://data.europa.eu/doi/10.2760/135208

Castaño-Muñoz, J., Weikert García, L., & Ministerio de Educación y Formación Profesional. (2021). The digital capacity of schools in Spain. Representative sample through SELFIE. Primary Education *(CINE-2011 1).* Publications Office. https://data.europa.eu/doi/10.2760/346765

Claro, M., Preiss, D. D., San Martín, E., Jara, I., Hinostroza, J. E., Valenzuela, S., Cortes, F., & Nussbaum, M. (2012). Assessment of 21st century ICT skills in Chile: Test design and results from high school level students. *Computers & Education*, *59*(3), 1042-1053. https://doi.org/10.1016/j.compedu.2012.04.004

Coller, X. (2005). *Case study*. CIS.

Cuban, L. (2015, October 20). Does integrating computers into lessons mean that teaching has changed? Larry Cuban on School Reform. https://larrycuban.wordpress.com/2015/10/20/does-integrating-computers-into-lessons-mean-that-teaching-has-changed/

Dussel, I. (2017). Perspectives, tensions and limits in the evaluation of 1:1 policies in Latin America. In S. B. Larghi & R. W. Iparraguirre (Eds.), Digital Inclusion: a critical look at the evaluation of de 1:1 model in Latin America (pp. 143-164). Teseo.

Erstad, O. (2010). Educating the Digital Generation. *Nordic Journal of Digital Literacy*, *5*(01), 56-71.

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research and Development, 53*(4), 25–39. http://www.jstor.org/stable/30221207

European Commission. (2006). Recommendation of the European Parliament and of the Council of 18 December 2006 on key competences for lifelong learning. In *OJ L,* L394. http://data.europa.eu/eli/reco/2006/962/oj/eng

European Commission. (2018a). Council Recommendation of 22 May 2018 on key competences for lifelong learning (Text with EEA relevance). *Official Journal of the European Union,* C 189/01. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018H0604%2801%29&qid=1643797485584

European Commission. (2018b). *Country report Spain 2018 including an in-depth review on the prevention and correction of macroeconomic imbalances*. https://ec.europa.eu/info/sites/default/files/2018-european-semester-country-report-spain-en.pdf

European Commission (2020a). *Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee of Regions. Digital Education Action Plan 2021-2027 Resetting education and training for the digital age*, (2020) (testimony of European Commission). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0624

European Commission. (2020b). *European Skills Agenda for Sustainable Competitiveness, Social Fairness and Resilience*. https://ec.europa.eu/social/BlobServlet?docId=22832&langId=en

European Commission. (2021). *Member States' digital progress through the Digital Economy and Society Index (DESI)*. https://ec.europa.eu/newsroom/dae/redirection/document/80563

Ferrari, A. (2013). *DIGCOMP: A framework for developing and understanding digital competence in Europe*. http://digcomp.org.pl/wp-content/uploads/2016/07/DIGCOMP-1.0-2013.pdf

Fraga-Varela, F., & Alonso-Ferreiro, A. (2016). Presence of digital Textbook in Galicia (Spain): A statistical-geographic snapshot of the E-DIXGAL Project. *Profesorado. Revista de Curriculum y Formación de Profesorado, 20*(1), 91-112. https://digibug.ugr.es/handle/10481/42554

Fraga-Varela, F., Vila-Couñago, E., & Martínez-Piñeiro, E. (2020). Information and Data Literacy of Galician (Spain) tweens: a mixed study. *RISTI - Revista Ibérica de Sistemas e Tecnologias de Informação*, *38*, 17-32. https://doi.org/10.17013/risti.38.17-32

Fullan, M. (2001). *The new meaning of educational change*. Routledge.

Gewerc, A., & Armando, J. (2016). New literacies in the intellectual field of education: Mapping theoretical perspectives in scientific publications. In D. Fonseca & E. Redondo (Eds.), *Handbook of research on applied E-learning in engineering and architecture education* (pp. 88-113). Engineering Science Reference.

Glaser, B. G., & Strauss, A. L. (1967). *The Discovery of grounded theory: Strategies for qualitative research.* Aldine Publishing.

González-Bueno, G. (2014). Child Poverty and Crisis Impact on Chilhood. *Educación y futuro: revista de investigación aplicada y experiencias educativas*, (30), 109-126.

Howard, S. K., Chan, A., & Caputi, P. (2015). More than beliefs: Subject areas and teachers' integration of laptops in secondary teaching. *British Journal of Educational Technology*, *46*(2), 360-369. https://doi.org/10.1111/bjet.12139

Kampylis, P., Punie, Y., & Devine, J. (2015). Promoting effective digital-age learning. *A European Framework for Digitally Competent Organisations.* http://publications.jrc.ec.europa.eu/repository/bitstream/JRC98209/jrc98209_r_digcomporg_final.pdf

Martin, A. (2006). A European framework for digital literacy. *Nordic Journal of Digital Literacy*, *1*(02), 151-161. https://doi.org/10.18261/ISSN1891-943X-2006-02-06

Martin, A. (2008). Digital literacy and the digital society. *Digital literacies: Concepts, policies and practices*, *30*, 151-176. https://doi.org/10.4236/ce.2017.810110

Martin, A., & Grudziecki, J. (2006). DigEuLit: Concepts and tools for digital literacy development. *Innovation in Teaching and Learning in Information and Computer Sciences*, *5*(4), 249-267. https://doi.org/10.11120/ital.2006.05040249

Miles, M., & Huberman, A. M. (1994) *Qualitative data analysis: A sourcebook of new methods*. Sage.

Muñoz, J., & Sahagún, M. A. (2010). Qualitative computer-aided análisis with ATLAS.ti. In C. Izquierdo & A. Perinat (Coords.) *Investigar en psicología de la comunicación. Nuevas perspectivas conceptuales y metodológicas* (pp. 301-364). Amentia.

Öqvist, A., & Högström, P. (2018). Don't ask me why: Preschool teachers' knowledge in technology as a determinant of leadership behavior. *Journal of Technology Education*, *29*(2), 4-19. http://doi.org/10.21061/jte.v29i2.a.1

Order of June 28 (2010) (Galicia, Spain). https://www.xunta.gal/dog/Publicados/2010/20100706/Anuncio21E16_es.pdf

Organic Law 3/2020 of Education (2020) (Spain). https://www.boe.es/eli/es/lo/2020/12/29/3/con

Redecker, C., & Punie, Y. (2017). Digital competence framework for educators (DigCompEdu). *European Union*. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC107466/pdf_digcomedu_a4_final.pdf

Rockwell, E. (2008). From Field to Text: Dilemmas of ethnographic work. In M. I. Jociles Rubio & A. Franzé Mudanó (Eds.). ¿Es la escuela el problema?: Perspectivas socio-antropológicas de etnografía y educación (pp. 90-111). Trotta.

Sadera, W., & Parrish, A. (2018). Teaching Competencies for Student-Centered, One-to-One Learning Environments: A Delphi Study. *Journal of Educational Computing Research*, *57*. https://doi.org/10.1177/0735633118816651

Sala, A., Punie, Y., Garkov, V., & Cabrera, G. M. (2020, julio 3). *LifeComp: The European Framework for Personal, Social and Learning to Learn Key Competence*. JRC Publications Repository. https://doi.org/10.2760/302967

Salinas-Amescua, B. (2007). Adult instructors' perceptions on ICT and diffusion practices: implications for equity of access. *Canadian Journal of Learning and Technology / La revue canadienne de l'apprentissage et de la technologie 33*(2). https://doi.org/10.21432/T2P01K

San Martín, Á., Peirats Chacón, J., & Gallardo, M. (2014). Smart Educational Centre. Lights and shadows on the policies of technological transferences and teaching practice. *Profesorado. Revista de currículum y formación del profesorado*, *18*(3), 63-79.

Selwyn, N. (2004). Reconsidering political and popular understandings of the digital divide. *New Media & Society*, *6*(3), 341-362. https://doi.org/10.1177/1461444804042519

Selwyn, N. (2011). Technology, media and education: Telling the whole story. *Learning, Media and Technology*, *36*(3), 211-213. https://doi.org/10.1080/17439884.2011.572977

Selwyn, N. (2014). Education and 'the digital'. *British Journal of Sociology of Education*, *35*(1), 155-164. https://doi.org/10.1080/01425692.2013.856668

Selwyn, N., & Facer, K. (2007). *Beyond the digital divide*. Futurelab. http://archive.futurelab.org.uk/resources/documents/opening_education/ Digital_Divide.pdf

Selwyn, N., & Facer, K. (Eds.). (2013). *The politics of education and technology. Conflicts, controversies, and connections*. Palgrave Macmillan.

Selwyn, N., & Husen, O. (2010). The educational benefits of technological competence: An investigation of students' perceptions. *Evaluation & Research in Education*, *23*(2), 137-141. https://doi.org/10.1080/09500790.2010.483515

Simons, H. (2009). *Case study research in practice*. Sage.

Stake, R. E. (1995). *The art of case study research*. Sage.

Valiente, Ó. (2011). Models 1:1 in education. International practices, comparative evidence and policy implications. *Revista Iberoamericana de Educación*, *56*, 113-134. https://doi.org/10.35362/rie560513

van Dijk, J. (2005). *The deepening divide: Inequality in the information society*. Sage.

van Dijk, J. & van Deursen, A. (2014). *Digital skills: Unlocking the information society* (First edition). Palgrave Macmillan.

Vekiri, I. (2010). Socioeconomic differences in elementary students' ICT beliefs and out-of-school experiences. *Computers & Education*, *54*(4), 941-950. https://doi.org/10.1016/j.compedu.2009.09.029

Vuorikari, R., Kluzer, S., & Punie, Y. (2022). *DigComp 2.2: The Digital Competence Framework for Citizens - With new examples of knowledge, skills and attitudes*. JRC Publications Repository. https://doi.org/10.2760/115376

Xunta de Galicia. (2010). *Integration of ICT in educational practice.* http://www.edu.xunta.gal/portal/sites/web/files/protected/content_type/file/2010/03/10/20100308_presentacion_abalar.pdf

Yin, R. K. (2017). *Case study research and applications: Design and methods.* Sage.

Zhong, Z.-J. (2011). From access to usage: The divide of self-reported digital skills among adolescents. *Computers & Education*, *56*(3), 736-746. https://doi.org/10.1016/j.compedu.2010.10.016

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University Learners' Motivation and Experiences in Using Virtual Laboratories in a Physics Course

Motivation et expériences des apprenants universitaires dans l'utilisation de laboratoires virtuels dans un cours de physique

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Abstract

It is becoming necessary to examine learners' use of and experiences with virtual laboratories. Learners' interest and motivation to use virtual laboratories are important factors for the success of these platforms. This study was conducted to analyze Kyrgyz learners' use of virtual laboratories in a physics course at the university level. The study was performed in the 2019–2020 spring term at a state university in Kyrgyzstan. The study took a quantitative approach, with 376 Kyrgyz learner participants studying at the undergraduate level. The participants were divided into three groups: the first and second used different virtual laboratory platforms, while the third was involved in face-to-face labs. Quantitative data were collected using an online questionnaire which consisted of items related to demographic characteristics, motivation and experience, and physics laboratory attitudes. The results demonstrated differences among the groups regarding factors of motivation and experience. In addition, learners' physics laboratory attitudes differed with respect to gender and grade point average (GPA) factors.

Keywords: Virtual lab; Physics; Motivation; Experience; Attitude

Résumé

Il devient nécessaire d'examiner l'utilisation et les expériences des apprenants avec les laboratoires virtuels. L'intérêt et la motivation des apprenants à utiliser les laboratoires virtuels sont des facteurs importants pour le succès de ces plateformes. Cette étude a été menée pour analyser l'utilisation des laboratoires virtuels par les apprenants kirghizes dans un cours de physique au niveau universitaire. L'étude a été réalisée au cours de la session de printemps 2019-2020 dans une université d'État du Kirghizistan. L'étude a adopté une approche quantitative, avec 376 participants apprenants kirghizes étudiant au premier cycle universitaire. Les participants ont été répartis en trois groupes : le premier et le deuxième ont utilisé différentes plateformes de laboratoire virtuel, tandis que le troisième groupe a participé à des laboratoires en présentiel. Les données quantitatives ont été recueillies à l'aide d'un questionnaire en ligne comprenant des éléments relatifs aux caractéristiques démographiques, à la motivation et à l'expérience, ainsi qu'aux attitudes à l'égard des laboratoires de physique. Les résultats ont démontré des différences entre les groupes concernant les facteurs de motivation et d'expérience. De plus, les attitudes des apprenants en laboratoire de physique différaient en ce qui concerne les facteurs de genre et de moyenne pondérée cumulative (MPC).

Mots clés : Laboratoire virtuel ; Physique ; Motivation ; Expérience ; Attitude

Introduction

In the physics discipline, laboratories have active and important roles as learners need to detect hidden concepts, and comprehend and define related principles and theories, while employing high level learning skills (Bajpai, 2013). The discipline of physics has a close connection with instructional technologies since there exist several abstract concepts in the field. At the same time, there are limited materials in existing laboratories for conducting experiments in physics courses. Therefore, instructors need various technologies in order to demonstrate physics concepts and experiments (Gunawan et al., 2018).

One of the significant instructional technologies used in science education is the virtual laboratory, whose use has been increasing in physics courses. A virtual laboratory is defined as "a combination of hardware and software systems that allows [a user] to conduct physics related or other domains (e.g., chemistry, etc.) experiments without direct contact with an actual equipment" (Daineko et al., 2017, p. 40). In virtual laboratories, learners are provided virtual illustrations of objects which commonly exist in traditional laboratories. Hence, learners gain the opportunity to learn by doing in these virtual environments (Abou Faour & Ayoubi, 2017).

In a state university of Kyrgyzstan, virtual laboratory technologies have been employed in the context of a general physics course. Since Kyrgyzstan would be deemed a developing country, essential materials do not exist in all university laboratories. Virtual laboratories have become a significant solution, giving learners practical experience. Learners can study theoretical concepts through face-to-face or online sessions, and then perform experiments in real or virtual settings. Within this general physics course, learners have the chance to enter a web-based learning environment in which they can access interactive models, animations, constructors, videos, virtual laboratories, and online quizzes (Muhametjanova & Akmatbekova, 2019). Learners are provided with access to one of two different virtual laboratories: Tina and Multisim. With these platforms, there are virtual demonstrations of real experiments, and learners can then carry out their own experiments, choosing from various options.

It is becoming necessary to examine learners' use of and experience with virtual laboratories. Learners' interest and motivation are important factors for the success of these platforms (Estriegana et al., 2019). In the meantime, there is a lack of research into the situation in Kyrgyzstan for the purpose of investigating learners' motivation and experience regarding virtual laboratories. Thus, this study is one of the first of its kind. This study aimed to analyze university learners' motivation to use virtual laboratories and understand their related experiences and attitudes towards physics.

Literature Review

Practices are considered as inseparable processes during science education (Maulidah & Prima, 2018). Virtual laboratories have been developed as significant instructional technologies in order to provide implementation of practices in an online environment. Using virtual laboratories, students are allowed to be active in their learning, comprehend complex concepts more easily, and repeat demonstrations (Falode, 2018).

With virtual laboratories, instructors can design labs that illustrate physics concepts and learners can comprehend these concepts through related practice (Masril et al., 2018). Virtual laboratories bring several benefits for learners, instructors, and institutions: (a) experiments can be implemented in a time-effective manner, (b) dangerous experiments can be performed on secure platforms, (c) experiments which actually cannot be implemented in real-life settings can be conducted, (d) virtual laboratories may be less expensive than traditional laboratories, (e) they may allow learners to proceed at their preferred pace, and (f) they can present immediate feedback to learners (Aşiksoy & Islek, 2017).

The effects of using virtual laboratories in physics education have been analyzed in several studies. Ranjan (2017) investigated the effects of virtual laboratories on learners' development of concepts and skills in physics. The results of the study demonstrated that students' conceptual learning related to the photoelectric effect was higher in virtual laboratories than in real laboratories. Gunawan et al. (2017) examined the effects of virtual laboratories on learners' problem-solving abilities in the context of an electricity concept. According to study results, learners using virtual laboratories showed higher-level problem-solving skills as compared to those using traditional laboratories. Diani et al. (2018) analyzed whether virtual laboratories decreased learners' misconceptions about fluid material concepts. The results were positive, and learners' misconceptions diminished after the use of virtual laboratories. Yusuf and Widyaningsih (2020) analyzed learners' benefits after the implementation of virtual laboratories and found that there was an increase in learning quality and metacognitive skills in physics experiment courses.

Considering motivational and self-efficacy aspects, Dyrberg et al. (2017) proposed a framework for the assessment of learner motivation and experiences in virtual laboratories. Their framework mainly covered two major factors: task value and self-efficacy. Task value considers learners' perceived value of the task and covers four sub-constructs: "(1) attainment value: importance to do the task well, (2) intrinsic (interest) value: enjoyment while doing the task and interest in the content, (3) utility value: usefulness and relevance of the task, and (4) cost beliefs: effort and time to be invested" (Dyrberg et al., 2017, p. 362). Self-efficacy refers to an individual's perception of his own ability to conduct a task (Bandura, 1986). Higher values of these two major factors result in higher motivation to engage in virtual laboratories.

Attitude is defined as “a form of psychological state that determines the response of a stimulus in the form of action or behavior” (Saputra et al., 2020, p. 1). Attitudes towards courses have been investigated, and while positive attitudes have been shown to result in high performance, negative attitudes result in difficulties in learning (Mushinzimana & de la Croix Sinaruguliye, 2016). Attitudes toward physics can be divided into four categories: (a) having good emotions about physics, (b) having pleasure while learning physics, (c) comprehending problems, and (d) understanding experiments in learning physics (Sitotaw & Tadele, 2016). The literature has revealed that there is a lack of research analyzing learners’ attitudes toward physics experiments (Saputra et al., 2020). On the other hand, it is essential to understand learners’ attitudes to physics laboratories for the achievement of learners’ motivations and learning in the field (Tanrıverdi & Demirbaş, 2012). In addition, laboratories are integrated components of physics courses. Hence, learners’ attitudes towards physics laboratories needs to be investigated.

In the context of this study, the questionnaire proposed by Dyrberg et al. (2017) was deemed appropriate for analyzing Kyrgyz learners’ motivation and experiences related to virtual laboratories. This survey had not been applied to Kyrgyz learners in prior studies. In this respect, our study is the first to present significant results about Kyrgyz learners’ motivations and experiences in the use of virtual laboratories in a physics course. In addition, this study aimed to investigate Kyrgyz learners’ attitudes towards physics laboratories while at the same time considering demographic characteristics. The corresponding results will be important for understanding learners’ attitudes and hence motivations and learning in the physics field.

Methodology

Research Questions

The purpose of this study was to investigate Kyrgyz learners’ use of virtual laboratories in a physics course at the university level. There were nine main research questions in the study:

1. In terms of Dyrberg et al.’s (2017) attainment factor, is there any difference among learners who participate in face-to-face laboratories, the ones who use the Tina platform, and the ones who use Multisim?
2. In terms of Dyrberg et al.’s (2017) utility value factor, is there any difference among learners who participate in face-to-face laboratories, the ones who use Tina, and the ones who use Multisim?
3. In terms of Dyrberg et al.’s (2017) intrinsic interest value factor, is there any difference among learners who participate in face-to-face laboratories, the ones who use Tina, and the ones who use Multisim?

4. In terms of Dyrberg et al.'s (2017) cost beliefs value factor, is there any difference among learners who participate in face-to-face laboratories, the ones who use Tina, and the ones who use Multisim?
5. In terms of Dyrberg et al.'s (2017) self-efficacy factor, is there any difference among learners who participate in face-to-face laboratories, the ones who use Tina, and the ones who use Multisim?
6. Is there any difference in physics laboratory attitudes between learners who use a virtual lab program (Tina and Multisim) and learners who participate in face-to-face laboratories?
7. Do learners' physics laboratory attitudes differ according to their faculties?
8. Do learners' physics laboratory attitudes differ according to their genders?
9. Do learners' physics laboratory attitudes differ according to their GPA?

Research Design and Participants

The study was conducted during the 2019–2020 spring term and employed a quantitative approach. Quantitative data were gathered from university level learners registered to a state university of the Kyrgyz Republic. Before collecting data, informed consent was acquired from participants. Data were gathered through an online questionnaire, which consisted of demographic questions, items related to the use of virtual laboratories, and items to measure physics laboratory attitudes.

A total of 376 Kyrgyz learners studying at the undergraduate level participated. Demographic profiles of participants are provided in Table 1. Participants were studying in the engineering or science faculties. Of the participants, 36.7% used the Tina virtual lab, 32.2% used the Multisim virtual lab, and 31.1% used real (i.e., face-to-face) laboratories.

Table 1

Demographic Data of Participants

Characteristic	Category	*n*	%
Gender	Male	138	36.7
	Female	238	63.3
Faculty	Engineering	292	77.7
	Science	84	22.3
Laboratory type used	Tina virtual lab	138	36.7
	Multisim virtual lab	121	32.2
	Face-to-face lab	117	31.1

Note. *N* = 376.

Setting

This study was performed in the context of an undergraduate level general physics course in a state university in Kyrgyzstan. This course was provided in two different faculties: engineering and science.

In this general physics course, there were two hours of lectures and two hours of laboratory sessions each week and a total of 14 weeks in the course. In the theoretical sessions, learners were introduced to topics of general physics. In the laboratory sessions, learners conducted experiments on corresponding topics in either a traditional laboratory or by using applications in a virtual laboratory.

Learners were provided with one of two different virtual laboratory options: Tina or Multisim. Sample screenshots of these platforms are shown in Figures 1 and 2, respectively. In these platforms, learners were provided with virtual demonstrations of real experiments and then given the opportunity to conduct experiments choosing from among various experiment options.

Figure 1

Sample Tina Screen

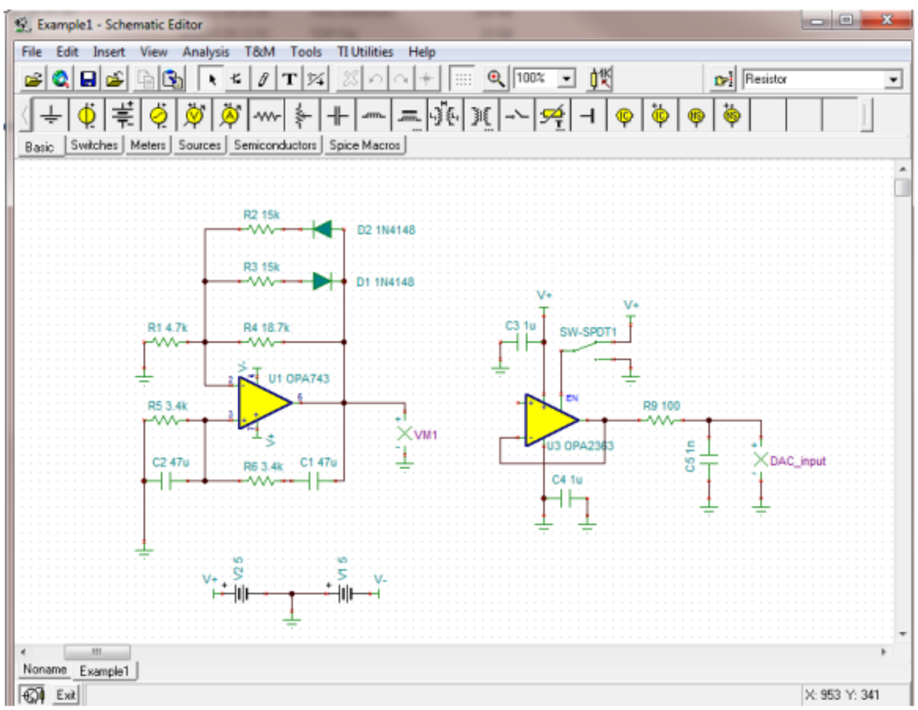
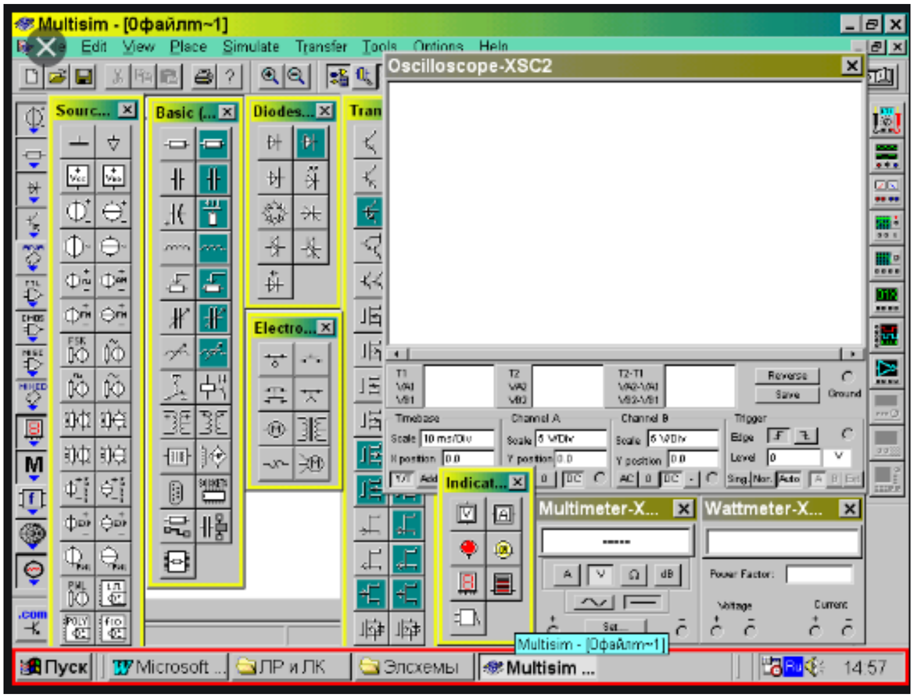


Figure 2

Sample Multisim Screen



Data Collection and Analysis

Data were gathered from participants through a questionnaire with three main sections. The first section covered five demographic questions. The second section involved questions related to task value, utility value, intrinsic interest value, cost beliefs, and self-efficacy. The third section consisted of the physics laboratory attitude scale. Items in the second and third sections were rated using a 5-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*).

The questionnaire was prepared in an online platform, and a link to the questionnaire was sent to learners registered in the general physics course that term. The questionnaire was completed on a voluntary base. Quantitative data were analyzed using IBM SPSS Statistics (Version 22). In our inquiry, both descriptive and inferential analysis were employed.

Results

Chi-square tests were applied to investigate the difference of factors (i.e., attainment, utility value, intrinsic interest value, cost beliefs value, and self-efficacy) and laboratory attitudes among learners in the three groups. The results are provided in Table 2.

The chi-square results demonstrated that there was significant difference between the three groups with respect to the values of utility, intrinsic interest, and cost-belief.

Table 2

Chi-Square Results Related to Factors

Factor	Value	*df*	Asymptotic significance (2-sided)
Attainment	13.844[a]	8	.086
Utility value	36.392[a]	22	.028
Intrinsic interest value	28.148[a]	16	.030
Cost beliefs value	50.301[a]	24	.001
Self-efficacy	40.541[a]	34	.204
Physics laboratory attitude	148.090[a]	150	.529

Note. *N = 376. [a]0 cells (0.0%) have expected count less than 5.*

Research Question 1 (Attainment Factor)

The chi-square results demonstrated that there was no statistically significant difference between the three groups in terms of attainment factor.

Research Question 2 (Utility Value)

Post-hoc tests demonstrated that users of the Multisim program had significantly higher utility value scores compared to users of Tina. Furthermore, users of face-to-face laboratories had significantly higher utility value scores compared to users of Tina.

Research Question 3 (Intrinsic Interest Value)

Differences were seen in the results of post-hoc tests. Users of the Multisim program had significantly higher intrinsic interest compared to users of Tina. Moreover, users of face-to-face laboratories also had significantly higher intrinsic interest compared to users of Tina.

Research Question 4 (Cost Beliefs Value)

The post-hoc tests revealed that users of face-to-face laboratories had significantly higher cost beliefs value scores compared to users of Tina.

Research Question 5 (Self-Efficacy)

The chi-square results demonstrated no statistically significant difference between the three groups in terms of the self-efficacy factor.

Research Question 6 (Physics Laboratory Attitudes)

According to the chi-square results, there was no statistically significant difference between the three groups in terms of learners' attitudes towards the physics laboratory.

Furthermore, chi-square tests were applied to see whether learners' physics laboratory attitudes differed according to their faculties, genders, and GPAs. The results are provided in Table 3.

Table 3

Chi-Square Results With Respect to Learners' Faculty, Gender, and GPA

Demographic characteristic	Value	*df*	Asymptotic significance (2-sided)
Faculty	73.856[a]	75	.516
Gender	96.427[a]	75	.049
GPA	9.998[a]	4	.040

Note. *N = 376. [a]0 cells (0.0%) have expected count less than 5.*

Research Question 7 (Faculty)

The results demonstrated that there was no significant difference between learners studying in the engineering faculty versus those studying in the science faculty in terms of their physics laboratory attitudes.

Research Question 8 (Gender)

There was a statistically significant difference between male and female learners regarding their physics laboratory attitudes. Female learners' attitudes were found to be higher than male learners' attitudes.

Research Question 9 (GPA)

The results showed that learners' physics laboratory attitude differed according to their GPA. Learners with higher GPAs also had higher physics laboratory attitude values.

Discussion and Conclusion

This study investigated Kyrgyz learners' use of virtual laboratories in a physics course provided at the university level. The total number of participants was 376, all of whom were studying at the undergraduate level. Among the participants, one group used the Multisim virtual laboratory platform, one used the Tina virtual laboratory platform, and one was involved in face-to-face labs. Task value, self-efficacy, physics laboratory attitude levels, as well as course performance of learning groups were investigated.

According to the initial results, users had similar task value scores. Attainment value refers to the importance of doing the task well; students using Multisim, Tina, as well as a face-to-face laboratory perceived doing laboratory experiments well. Yet, Multisim and face-to-face laboratory users experienced more enjoyment while doing experiments in the context of the intrinsic interest factor, and they found the tasks useful and relevant in the context of the utility factor. In addition, learners using face-to-face laboratories demonstrated significantly higher cost beliefs value scores compared to users of the Tina program. These results are both similar and dissimilar to the study of Dyrberg et al. (2017), which found low task value scores of virtual lab users compared to traditional lab users. The similar level of task value scores in these virtual lab programs may have originated from instructional design issues. Therefore, there is a need to enhance the programs to attain better results. For instance, tasks in the Tina program can be improved by adding more experimental works or by integrating more joyful activities. In this way, learners could benefit more from the program.

Self-efficacy considers an individual's perceived ability to perform a task. In this study, users of face-to-face laboratories and virtual laboratories were found to have similar self-efficacy scores. According to the literature, various findings have been seen in the results of other studies. For instance, Kolil et al. (2020) with an experimental self-efficacy framework found that both traditional and virtual laboratory users had low level experimental self-efficacy scores. Yet, the study of Ghatty (2013) revealed that learners using a virtual laboratory in a physics course experienced significant self-efficacy gains compared to learners using traditional laboratories. Further, this study also revealed that virtual laboratory users had similar self-efficacy scores compared to traditional laboratory users. This may be due to learners' lack of technology knowledge and fear of performing experiments in a computer-based environment. This issue can be solved with student orientation sessions at the beginning of term. Furthermore, instructors can provide additional support to learners. In this way, learners may not hesitate to become involved in virtual laboratories. Moreover, some learners will increase their achievement when using virtual laboratories.

In the context of other research questions, learners' physics laboratory attitudes were investigated according to the type of laboratories they were involved in and from the perspective of demographic characteristics. The findings revealed that learners' physics laboratory attitudes did not change whether they used virtual or traditional laboratories. This implies that learner groups have similar motivation and achievement scores in physics courses. The same results can be seen in the study of Abou Faour and Ayoubi (2017), which found no significant attitude difference between virtual laboratory and face-to-face laboratory users in a physics course. Yet, the study of Tüysüz (2010) revealed that learners using a virtual laboratory demonstrated a higher-level attitude in comparison to traditional instructional methods. This can be explained by the existence of the benefits provided by virtual laboratories. For example, virtual laboratories provide opportunities to carry out dangerous experiments in safe environments and to perform experiments in schools that do not have sufficient laboratory equipment. Therefore, users of virtual laboratories showed higher motivation to perform experiments.

In this current study, there was not a significant physics laboratory attitude difference between learners studying in different faculties. That is, learners from both engineering and science showed similar motivation and achievement levels in the context of their physics laboratory courses. On the other hand, significant attitude differences were found between male and female learners. That is, female learners' attitudes were found to be higher than male learners' attitudes. In the study of Winkelmann et al. (2020), males and females demonstrated identical attitudes towards physics experiments conducted in an immersive virtual world. This study additionally revealed that learners having a higher GPA also had higher physics laboratory attitude values. This is an expected result since there is correlation between success and motivation. Similarly, Tüysüz (2010) focused on implementation of virtual laboratory applications and explored the direct correlation between learner performance and attitudes.

The results of this study are limited to the state university in Kyrgyzstan. Since the situation with the general information and communication technology (ICT) level of students varies depending on university, it is not possible to generalize the results of this study. Moreover, results showed that those students who used the Multisim virtual laboratory had generally higher utility value and intrinsic interest than students in the face-to-face group and in the Tina virtual laboratory. This might be explained by the fact that students using Multisim had higher ICT levels of literacy, and consequently, higher motivation to learn in general physics courses. Furthermore, the Multisim virtual laboratory is more user-friendly than the Tina virtual laboratory. The Tina platform is more complex and not user friendly. This may explain the lower motivation of students using Tina. In future studies, we suggest researchers compare students' achievement for groups from the same department and include a larger number of students, so they can be divided into 3 subgroups, each using a different virtual laboratory. Learning physics is a comprehensive task and having software such as Multisim and Tina offers an advantage to students of specific departments.

Overall, this study has shed light on learners' experiences and motivations in using virtual and face-to-face laboratories. The results demonstrate differences and similarities between Multisim, Tina, and face-to-face users. Yet, investigating and understanding learner experiences will allow instructors and developers to further improve the use of existing virtual laboratories. As a result, learners can benefit even more from this technology.

References

Abou Faour, M., & Ayoubi, Z. (2017). The effect of using virtual laboratory on grade 10 students' conceptual understanding and their attitudes towards physics. *Journal of Education in Science Environment and Health*, *4*(1), 54–68. https://www.jeseh.net/index.php/jeseh/article/view/131

Aşiksoy, G., & Islek, D. (2017). The impact of the virtual laboratory on students' attitudes in a general physics laboratory. *International Journal of Online and Biomedical Engineering (iJOE)*, *13*(04), 20–28. https://core.ac.uk/download/pdf/270196739.pdf

Bajpai, M. (2013). Developing concepts in physics through virtual lab experiment: An effectiveness study. *TechnoLEARN: An International Journal of Educational Technology*, *3*(1), 43–50. https://www.proquest.com/openview/8c8c4b07ff43286968b7bcfeba3238d0/1?pq-origsite=gscholar&cbl=2032154

Bandura, A. (1986). *Social foundations of thought and action – A social cognitive theory*. Prentice Hall.

Daineko, Y., Dmitriyev, V., & Ipalakova, M. (2017). Using virtual laboratories in teaching natural sciences: An example of physics courses in university. *Computer Applications in Engineering Education*, *25*(1), 39–47. https://doi.org/10.1002/cae.21777

Diani, R., Latifah, S., Anggraeni, Y. M., & Fujiani, D. (2018). Physics learning based on virtual laboratory to remediate misconception in fluid material. *Tadris: Journal of Education and Teacher Training*, *3*(2), 167–181. https://doi.org/10.24042/tadris.v3i2.3321

Dyrberg, N. R., Treusch, A. H., & Wiegand, C. (2017). Virtual laboratories in science education: Students' motivation and experiences in two tertiary biology courses. *Journal of Biological Education*, *51*(4), 358–374. https://doi.org/10.1080/00219266.2016.1257498

Estriegana, R., Medina-Merodio, J.-A., & Barchino, R. (2019). Student acceptance of virtual laboratory and practical work: An extension of the technology acceptance model. *Computers & Education*, *135*, 1–14. https://doi.org/10.1016/j.compedu.2019.02.010

Falode, O. C. (2018). Pre-service teachers' perceived ease of use, perceived usefulness, attitude and intentions towards virtual laboratory package utilization in teaching and learning of physics. *Malaysian Online Journal of Educational Technology*, *6*(3), 63–72. https://doi.org/10.17220/mojet.2018.03.005

Ghatty, S. L. (2013). *Assessing students' learning outcomes, self-efficacy and attitudes toward the integration of virtual science laboratory in General Physics* (Publication No. 3590390) [Doctoral dissertation, Southern University and Agricultural and Mechanical College]. ProQuest Dissertations Publishing.

Gunawan, G., Harjono, A., Sahidu, H., & Herayanti, L. (2017). Virtual laboratory to improve students' problem-solving skills on electricity concept. *Indonesian Journal of Science Education*, *6*(2), 257–264. https://doi.org/10.15294/jpii.v6i2.9481

Gunawan, G., Suranti, N. M. Y., Nisrina, N., Herayanti, L., & Rahmatiah, R. (2018). The effect of virtual lab and gender toward students' creativity of physics in senior high school. *Journal of Physics: Conference Series*, *1108*(1), 1–7. https://doi.org/10.1088/1742-6596/1108/1/012043

Kolil, V. K., Muthupalani, S., & Achuthan, K. (2020). Virtual experimental platforms in chemistry laboratory education and its impact on experimental self-efficacy. *International Journal of Educational Technology in Higher Education*, *17*(1), 1–22. https://doi.org/10.1186/s41239-020-00204-3

Masril, M., Hidayati, H., & Darvina, Y. (2018). The development of virtual laboratory using ICT for physics in senior high school. *IOP Conference Series: Materials Science and Engineering, 335*(2018), 1–8. https://doi.org/10.1088/1757-899X/335/1/012069

Maulidah, S. S., & Prima, E. C. (2018). Using physics education technology as virtual laboratory in learning waves and sounds. *Journal of Science Learning*, *1*(3), 116–121. https://doi.org/10.17509/jsl.v1i3.11797

Muhametjanova, G., & Akmatbekova, A. (2019). The web-based learning environment in general physics course in a public university in Kyrgyzstan. *EURASIA Journal of Mathematics, Science and Technology Education*, *15*(3), 1-8. https://doi.org/10.29333/ejmste/100409

Mushinzimana, X., & de la Croix Sinaruguliye, J. (2016). Attitude of physics students towards physics at College of Science and Technology–University of Rwanda. *Rwandan Journal of Education*, *3*(2), 1–10. https://www.ajol.info/index.php/rje/article/view/157206

Ranjan, A. (2017). Effect of virtual laboratory on development of concepts and skills in physics. *International Journal of Technical Research & Science, 2*(1), 15–21. https://ijtrs.com/uploaded_paper/EFFECT%20OF%20VIRTUAL%20LABORATORY%20ON%20DEVELOPMENT%20OF%20CONCEPTS%20AND%20SKILLS%20IN%20PHYSICS.pdf

Saputra, H., Suhandi, A., Setiawan, A., & Permanasari, A. (2020). Pre-service teacher's physics attitude towards physics laboratory in Aceh. *Journal of Physics: Conference Series*, *1521*(2), 1–7. https://doi.org/10.1088/1742-6596/1521/2/022029

Sitotaw, B., & Tadele, K. (2016). Student attitude toward physics in primary and secondary schools of Dire Dawa City Administration, Ethiopia. *World Journal of Educational Research and Reviews*, *2*(2), 14–21.

Tanrıverdi, G., & Demirbaş, M. (2012). Fizik laboratuarına yönelik tutum ölçeği geliştirme: Geçerlik ve güvenirlik çalışması [Developing an attitude scale towards physics laboratory: A study on validity and reliability]. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi (KEFAD), 13*(3), 83–101. https://dergipark.org.tr/en/pub/kefad/issue/59486/854936

Tüysüz, C. (2010). The effect of the virtual laboratory on students' achievement and attitude in chemistry. *International Online Journal of Educational Sciences*, *2*(1), 37–53. https://www.academia.edu/download/55398446/Effect_Virtual_lab.pdf

Winkelmann, K., Keeney-Kennicutt, W., Fowler, D., Lazo Macik, M., Perez Guarda, P., & Joan Ahlborn, C. (2020). Learning gains and attitudes of students performing chemistry experiments in an immersive virtual world. *Interactive Learning Environments*, *28*(5), 620–634. https://doi.org/10.1080/10494820.2019.1696844

Yusuf, I., & Widyaningsih, S. W. (2020). Implementing e-learning-based virtual laboratory media to students' metacognitive skills. *International Journal of Emerging Technologies in Learning (IJET)*, *15*(5), 63–74. https://pdfs.semanticscholar.org/4b34/adaa8cbc0b90fac867748422b15e843dbc27.pdf

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(Re)Framing Our Frames: Architectonics, Intertextuality, and the Scholarship of Integration in Online Education

(Re)Cadrer nos cadres: Architectonique, intertextualité et les savoirs sur l'éducation dans l'éducation en ligne

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Abstract

The pandemic of 2020 has renewed interest in technology as an integrative agent in higher education. However, advancements in technology continue to outpace the scholarship of integration in the Scholarship of Teaching and Learning (SoTL), even though American educator Ernest Boyer valued it as an area of continuous interdisciplinary inquiry. This thought piece calls for a reconsideration of Boyer's appreciation of integration as convergence or *intertextuality*. Intertextuality and its digital correlate or *hypertextuality* operationalize online education. Yet, they are often ignored as modes of convergence that challenge disciplinarity. This paradox signals a need for a scholarly discourse and framework that can help educators to (re)conceptualize the inherently integrative nature of knowledge and online education. To address this deficit in the SoTL, this meta-synthesis evidences Peircean architectonics as the paradigm that reframes our understanding of convergence and illuminates its actualization in Canadian educator Terry Anderson's prototype for online education theory. Architectonic logic enriches this model and provides online educators with a common discourse and interdisciplinary framework that will advance the scholarship of integration in online education.

Keywords: Architectonics; Digital interdisciplinarity; Intertextuality; Online education theory

Résumé

La pandémie de 2020 a renouvelé l'intérêt pour la technologie en tant qu'agent d'intégration dans l'enseignement supérieur. Cependant, les progrès de la technologie continuent de dépasser les savoirs concernant l'intégration dans l'Avancement des Connaissances en Enseignement et en Apprentissage (SoTL par ses sigles en anglais), même si l'éducateur américain Ernest Boyer l'a appréciée comme un domaine de recherche interdisciplinaire continue. Cet article de réflexion appelle à reconsidérer l'appréciation de Boyer de l'intégration en tant que convergence ou *intertextualité*.

L'intertextualité et son équivalent numérique ou *hypertextualité* rendent opérationnelle l'éducation en ligne. Pourtant, ils sont souvent ignorés en tant que modes de convergence qui remettent en cause la disciplinarité. Ce paradoxe signale le besoin d'un discours et d'un cadre savants qui peuvent aider les éducateurs à (re)conceptualiser la nature intrinsèquement intégrative des connaissances et de l'éducation en ligne. Pour combler ce déficit dans le SoTL, cette méta-synthèse met en évidence l'architectonique de Peircean comme le paradigme qui recadre notre compréhension de la convergence et éclaire son actualisation dans le prototype de l'éducateur Canadien Terry Anderson pour la théorie de l'éducation en ligne. La logique architectonique enrichit ce modèle et fournit aux éducateurs en ligne un discours commun et un cadre interdisciplinaire qui feront progresser les savoirs sur l'intégration dans l'éducation en ligne.

Mots clés : Architectonique ; Interdisciplinarité numérique ; Intertextualité ; Théorie de l'éducation en ligne

Introduction

In the wake of the pandemic of 2020, online education has emerged as a key feature in many academic systems around the world. This seismic shift in the organization of higher education has ignited a renewed interest in technology as an agent for democratic education and integrative teaching and learning (Alexander, 2020; Schwab & Malleret, 2020). However, advancements in technology continue to outpace the scholarship of integration in the Scholarship of Teaching and Learning (SoTL). As a result, the gap widens between educators who see technology as a tool for teaching and learning and those who see it as another vector that reproduces inequality between those with reliable access to advanced digital technology and those without it (Lemke, 2002; Picciano, 2019). The literature in SoTL tends to underplay this technological division and others (Kirkwood & Price, 2013). Unfortunately, we do not find many integrative concepts in the literature that help us to bridge the gaps in our different contexts and frameworks, particularly in online education (Huber & Morreale, 2002; Hutchings, 2000; Webb & Welsh, 2019; Weimer, 2006). Frameworks or *paradigms* are interpretative lenses. A frame constitutes the principles or worldviews that condition our understanding of complex phenomena. In education, frames are important because they serve as conceptual tools that help us to organize experiences and interpret meaning in ways that inform our practices (Goffman, 1986).

Hutchings and Huber (2008) would agree that the lack of framing or *theorizing* in SoTL is one of the tensions running through the field. This problem and its causations have interdisciplinary roots that point us in different directions. For example, the pluralism and flexibility found in the various perspectives and practices operating in SoTL are commendable but also problematic (Hutchings, 2000; Webb & Welsh, 2019). If we continue to encourage scholars from different disciplines to champion their frameworks and practices in SoTL, then we must attend to the conceptual divergences or differences as well as the convergences or interconnections that manifest (Huber & Morreale, 2002). In other words, SoTL welcomes pedagogical perspectives and innovations from across the disciplines with few studies on the commonalities that these areas share and their implications for improving teaching and learning in academe. Without a coherent integrative discourse to advance this process, our disciplinary concepts simply accumulate in silos and reinforce the academic boundaries and traditional practices that SoTL claims to transfigure (Werder, 2013). The following thought piece further explores this line of inquiry by examining what Boyer (1990) calls *the scholarship of integration*. In doing so, I turn to the philosophical ideas of Charles S. Peirce to reveal what we can learn when we revalue *integration* as the theory and practice of convergence or *intertextuality*. This shift in our conceptualization and worldview is necessary now that online education has emerged as an essential model for teaching and learning after the pandemic of 2020.

Background of the Problem

As the systematic evaluation and public presentation of teaching and learning, SoTL is essentially discipline-based with interdisciplinary pretensions. Scholars such as McKinney (2007) cue this ethos when they claim that "SoTL is very much discipline-based though we now have increasing work across the disciplines" (p. 11). In essence, faculty introduce ideas and pedagogical innovations from a variety of disciplines, and these gestures have come to signify rather than actualize interdisciplinarity in the field. However, this *work* often fails to elaborate or substantiate the discourse of integration that many interdisciplinarians see as a feature in interdisciplinary processes and practices (Klein, 1996, 2005). In fact, Werder (2013) concludes that the discipline-based current in the field still remains strong. She also finds that there is a noticeable gap in the discourse used to spotlight integrative learning in SoTL. In the age of the Internet, the discourse of integration impacts the work of online educators who are also interested in creating democratic spaces and interdisciplinary learning opportunities for students (Landow, 2006). Moreover, scholars and practitioners appear to face competing allegiances when it comes to contemplating the role that disciplinarity and interdisciplinarity should play in SoTL. This discordance evokes a troubling set of questions that have been succinctly articulated by Werder (2013, p. 248): Are we professionally more focused on disciplinarity rather than interdisciplinarity in SoTL? Could it be that we are simply more interested in deepening our allegiance and study of one academic domain rather than synthesizing it with others to improve teaching and learning in higher education? The silence that these questions often produces is at odds with the foundational ideas for the scholarship of integration that were first articulated by pioneering scholars such as Boyer (1987, 1990).

We might imagine Boyer's model of scholarship as a series of separate but intersecting domains or frames that transfigure our understanding of the relationship among teaching, learning, and scholarship in higher education. Boyer's frames are typically noted as the scholarship of discovery, integration, application (or engagement), and teaching and learning. The focus of this inquiry is the scholarship of integration. Boyer (1990) writes, "By integration, we mean making connections across the disciplines, placing the specialties in larger context, illuminating data in a revealing way, often educating nonspecialists, too" (p. 18). The author argues that the scholarship of integration is "disciplined work that seeks to interpret, draw together, and bring new insights to bear on original research" (p. 19). This often entails integrating different ideas and research into larger intellectual patterns and traditions. Boyer (1987, 1990) also identifies the connective processes and interactive practices that allow us to contextualize, interpret, and integrate specialized knowledge in ways that help us to discover important insights. In her brief historical overview of integration, Klein (2005) claims that the term first appeared in studies in psychology by thinkers such as Herbert Spencer and William James. It is important to note that William James acknowledged the substantial role that the philosopher, semiologist, and interdisciplinarian Charles S. Peirce played in advancing his thinking and that of others (see Parker, 1998). Klein (2005) does not expound on Peirce's contributions to education and the theory of integration (more on this below). Nevertheless, Klein does help us to understand the complex relationship between *interdisciplinarity* and *integration* in the learning process. In general, integrated learning is considered a strategy for presenting and relating content. Interdisciplinarity is a way of reframing and repositioning the disciplines in order to enable the integration of content. While interdisciplinarity tends to emanate from the disciplines, integration can emanate from almost anywhere (Dennis, 2020a; Klein, 1996; 2005).

Boyer's work and that of many scholars in SoTL advance the logic of integration as a way to enrich teaching and learning in all fields in higher education. According to Boyer (1990), the scholarship of integration asks us to privilege interdisciplinarity and explore "the boundaries where fields converge" (p. 19). In other words, *convergence* signals the various ways in which foundational technologies such as words, texts, and disciplines allow us to merge or network information in order to inspire transformative change and further opportunities for integrative teaching and learning. However, Boyer's prescient evocation of the term as a proclamation and principle remains underappreciated in SoTL. Weimer (2006) notes that the scholarship of integration is the least examined frame in Boyer's model of scholarship. Huber and Hutchings (2004) underpin this appraisal when they argue that integrative teaching and learning in higher education remain largely unrealized. Ultimately, this problem suggests that the scholarship of integration may resonate more as rhetoric than reality for many scholars and practitioners. However, the integration of knowledge and different practices is an increasingly important skill that teachers must acquire and negotiate, especially in online education (Bernauer & Tomei, 2015). It is only when we learn to think beyond our disciplinary frameworks and silos that we can begin to reimagine the "set of claims, activities, and institutional structures that define and protect knowledge practices" (Klein, 1996, p. 1). Ironically, knowledge-integration is essentially the job that educators expect computer technology to do even though many of us undervalue its integrative logic as a paradigm for our own professional and pedagogical activities (Bernauer & Tomei, 2015).

Chick (2013) reminds us that "there is still pressure, at least in the United States, toward a fairly narrow set of approaches in SoTL that limit the methods accepted as sound" (p. 15). She points out that methods in areas such as the natural and social sciences tend to be viewed more favorably than those associated with the humanities. Chick's assessment evidences the claim that professionalization in SoTL discreetly privileges disciplinarity rather than those forms of interdisciplinarity that model the kinds of integrative work that we need to improve teaching and learning in all areas of higher education. According to Hovland et al. (2015), modeling integration in higher education requires supportive leadership and innovative conceptual frameworks. Surprisingly, conceptual frameworks for online education are the theoretical tools that we continue to lack in SoTL. For example, Kirkwood and

Price (2013) have questioned just how effective technology has been in transforming teaching and learning in higher education. Although interest in technology-enhanced education has increased in SoTL, the authors claim that there are few accounts in the academic literature that evidence the use of scholarly approaches to guide our use of technology in the classroom. For them, the term *scholarly approach* describes the thoughtfulness that educators give to the ideas, concepts, and tools that they use to construct environments and conditions that effectuate teaching and learning. However, in their investigation, Kirkwood and Price (2013) discover that very few studies actually reference relevant theoretical ideas or models that explain how teaching and learning with technology are conceptualized. Thus, they would agree that we are long overdue for a more comprehensive discourse and paradigm for reflecting on the character of integration and how it might inform our thinking about teaching and learning in academic systems where online instruction is now a feature rather than an anomaly in the post-pandemic academy.

Purpose Statement

My goal is to explain how the architectonic philosophy of Charles S. Peirce might offer us the kind of interdisciplinary scholarly framework that we need in SoTL in order to guide our use of technology in academe. Also, I examine how Peircean architectonics recalibrates our understanding of integration as a form of convergence or what many postmodern theorists call *intertextuality*. According to Chandler (2002), intertextuality recognizes that words and texts are always interacting and effectuating new semiotic realities. In this discussion, the concept is also treated as a synonym for integration, reciprocity, and structural unboundedness. Chandler (2002) claims, “Intertextuality blurs the boundaries not only between texts but between texts and the world of lived experience” (p. 205). In this sense, it could also be considered a philosophy of learning that describes the process of meaning-making and exchange between humans and texts (Barthes, 1989; Halliday, 1978; Kristeva, 1986). As such, the combinative processes in intertextuality represent a form of constructivism or *architectonics* (Bakhtin, 1990; Hawkins, 1994). For this study, architectonics is valued as the cross-disciplinary term that scholars use to describe the systematic and constructivist nature of all relations and creations. As an interdisciplinary conceptual tool, architectonics has been used to elucidate ideas in the human, physical, and social sciences. Manchester (2003) suggests that the reason the concept has been influential in so many academic circles is its centrality in characterizing the creation, discourse, and networks that feature in all aspects of life and learning. Dennis (2020b) and Holquist (1990) elaborate this point even more when they characterize architectonics as a meditation on the complex process of creation and construction that enables meaning-making and sense-making in theory as well as practice. Also, Gazoni (2016) recognizes philosophers such as Peirce as one of the first thinkers to exploit the dialogic nature of architectonic processes in the operations of *logical machines* or the ancestors of modern computers. Peirce (1887, 1955) offers us the kind of philosophical perspective that we need in order to reimagine the kinship between integrated learning and intertextuality. More importantly, Peirce’s ideas anticipate the *hypertextuality* advanced by digital technology. As the electronic hyperlinks and texts that operationalize computerized devices, hypertextuality extends the logic of convergence and intertextuality into the digital world and online education (Nelson, 1987; Orr, 2003).

To illustrate this point, I will explain Peirce's theory of architectonics and identify the architectonic principles that constitute the conceptual framework that we need in order to understand intertextuality and hypertextuality as figurative equivalents or two modes of convergence that can inform our understanding of teaching and learning with technology. Using this paradigm as an interpretive lens, I will review the model of online education introduced by Anderson (2008) and reveal how the various modalities in his prototype actualize architectonics as a process that is essential to integrative teaching and learning online. More significantly, I reveal how architectonic logic also enriches Anderson's appreciation of *interaction* as an intertextual and hypertextual activity that effectuates online instruction. In the final analysis, the architectonic paradigm that is inspired by Peircean thought and modeled by Anderson's prototype signals the kind of synthesis and framework that we need in order to advance teaching and learning and the democratizing impulse inherent in online education.

Architectonics as Interdisciplinary Paradigm

Throughout his extensive body of work, Peirce (1955) advocates the use of philosophical thought to construct and connect knowledge. He does this by working across disciplines and standing on the shoulders of one of his most important intellectual predecessors, Immanuel Kant. According to Kant (2007), architectonics is the art of constructing systems, particularly systems of knowledge. Systems create the unity that is needed to transform knowing to the rank of science. Peirce (1955) says, "That systems ought to be constructed architectonically has been preached since Kant, but I do not think the full import of the maxim has by any means been apprehended" (p. 316). To help us realize the importance of Kant's contributions to constructivist thinking, Peirce appropriates Kantian architectonics and reverses its positivistic orientation (Parker, 1998). For instance, Peirce's reconsideration of the idea of a system of knowledge or *architectonics* provides us with a unique road map for observing the overlapping dimensions of knowledge or what we simply call *sciences* or academic disciplines today. His classification system for the disciplines contemplates the similarities and differences among them. Unlike Kant, Peirce (1955) privileges the similarities among the disciplines in his classification system.

The most distinguishing feature in Peirce's architectonics is the triadic logic that animates his arrangement of the disciplines. Peirce (1955) writes, "We find the ideas of first, second, third, constant ingredients of our knowledge" (p. 93). He argues that these three conceptions turn up in all interactive systems. In general, *firstness* represents a monadic relation. *Secondness* is a dyadic relation. *Thirdness* is the convergence of monadic and dyadic relations. *Convergence* is a key relation in Peircean architectonics because it characterizes the *synechism* or continuity that is the by-product of integrative forces and processes (Short, 2007). The logic of convergence and continuity is what Peirce uses to inform his understanding of the architectonic relations of all disciplines. As a result, Peirce (1955) claims that there are three disciplinary domains. The disciplines of discovery are first. Second are the disciplines of review. Both represent the theoretical disciplines. The practical disciplines are third. Peirce's triadic classification interrelates the sciences in terms of theory and practice. The discipline of discovery encompasses the three subcategories that are most noteworthy for this discussion (for a more comprehensive elaboration of Peirce's classification system, see Parker, 1998, and Short, 2007). The three subcategories in the discipline of discovery are mathematics, philosophy, and *idioscopy* or what we know as the physical and human sciences. Mathematics is first among the disciplines of discovery because mathematical reasoning is inherently combinative. It offers us the kind of connective concept that is indispensable to the other sciences. For instance, the term *synechism* or continuity has its roots in mathematical thought and is expressed as thirdness in Peirce's theory of architectonic relations.

For a clearer understanding of Peirce's disciplines of discovery, one might imagine mathematics as the algebra of all relations and the starting point for understanding the interconnected nature of all disciplines (Short, 2007). Philosophy derives its integrative essence from mathematics (synechism), and in turn, they both condition our understanding of the kinship and connections between the physical and human sciences. However, Peirce (1955) also identifies three interrelated subcategories in philosophy: phenomenology, metaphysics, and the *reasoning* or normative sciences. The normative sciences consist of aesthetics, metaphysics, ethics, and logic. Logic is important because it orients us toward the end of thought or action (i.e., pragmatism). More significantly, it is how we integrate and synthesize the knowledge that the disciplines organize and *logical machines* process. Whether observed in humans or machines, Peirce (1887, 1955) imagined logic as simply another name for *semeiotics*. He writes, "Logic, in its general sense, is, as I believe I have shown, only another name for semiotic…or formal, doctrine of signs" (1955, p. 98). Peirce often uses the term *semeiotic* instead of the more commonly used term *semiotic*. Semeiotics is essentially a conceptual tool for reasoning using a triadic understanding of all relations and experiences. Peirce (1955) describes the key components of this reasoning process in relation to his larger architectonic project. In one of his formulations of the sign, Peirce writes, "A sign, or Representamen, is a First which stands in such a genuine triadic relation to a Second, called its Object, as to be capable of determining a Third, called its Interpretant, to assume the same triadic relation to its Object in which it stands itself to the same Object" (pp. 99–100).

For added explanatory value, Witte (1992) asks readers to imagine Peirce's triadic relation and sign system in terms of texts or what Peirce might call an organized set of signs. In his reinterpretation, Witte (1992) substitutes the word *context* for the word *object*. The word *text* replaces the word *sign*. Peirce's term *interpretant* is replaced with the word *intertext*. This reframing extends the logic of Peircean architectonics into the world of texts by illustrating its continuity and convergences at the level of writing. Echoing Peirce, Witte (1992) reports that the relation of a text to its context is reciprocal and the relation of a text to its intertext is no different. As another synonym for integration, *reciprocity* describes a mutual exchange or convergence between different texts or other entities (Watson, 1993). In short, context, text, and intertext are not only reciprocal but nearly inseparable in Peircean thought.

In pioneering the idea of intertextuality as a form of reciprocity, pluralism, and democratic practice in semiotics, Kristeva (1986) further evidences Peircean logic when she claims, "each word (text) is an intersection of word (texts) where at least one other word (text) can be read" (p. 37). When he coined and developed the term *hypertextuality,* Nelson (1987) essentially extends the logic of intertextuality into the digital world of information technology, thus echoing Peirce's (1887) work on logical machines. For Nelson (1987), hypertext is the non-sequential and multidimensional blocks of texts with branches and links that offer individuals different pathways and connections to information. It is a form of electronic writing that is antifoundational, performative, and best illustrated on a computer screen. More importantly, hypertexts operationalize the Internet and the computerized devices that allow us to navigate its limitless terrain. As a medium with democratic and integrative qualities, hypertextuality is "a fundamentally intertextual system" that values supplementation and change (Landow, 2006, p. 55). In essence, hypertextuality is intertextuality reimagined for a world that rationalizes itself through computerized devices and the vast digital networks that allow us to cross space and time (Orr, 2003). With this in mind, architectonics simply articulates the networking process as it relates to the social construction of texts, (inter)disciplines, and their convergence through *intertextuality* and its digital equivalent or *hypertextuality*. In architectonic thought, these are twin concepts for simultaneity, systematicity, and constructivism (Hawkins, 1994; Holquist, 1990). The theoretical significance of this kinship reorients and *matures* the ideas of thought leaders and theorists in online education (Dennis, 2018, 2020b; Landow, 2006; Orr, 2003; Picciano, 2019).

However, Sharples et al. (2006) are just a few of the critics who have called for a complete revaluation of our philosophical understandings of teaching, learning, and technology in the twenty-first century. Echoing Peirce, Sharples et al. (2006) argue that technology and semiotic interrelations converge and diverge in digitalized networks, thus generating the artefacts at the center of all teaching and learning with computerized devices. The networking capacity that characterizes these domains represents what Lemke (1992) calls the *cornerstone* of how meanings are made in the brave new world of advanced technology. Lemke (1992, 2002) and Sharples et al. (2006) would agree that intertextuality and hypertextuality are critical areas of educational research. This is likely to remain the case as we become increasingly reliant on computer technology for teaching and learning in the future. This focus on texts and technology might explain why interdisciplinary thinkers such as McKeon (1987), Watson (1993), Klein (1996, 2010), Foucault (2010), Hovestadt (2010), and Dennis (2020a, 2020b) have posited the *discourse of architectonics* as a starting point for advancing the integrative logic of intertextuality and interdisciplinarity in higher education. In exploring how intertextuality helps to bridge the gap between interdisciplinarity and the scholarship of integration, Dennis (2020a) introduces the architectonic principles that serve as the kind of paradigm and synthesis that we need to reframe the interrelationship between teaching, learning, and technology.

According to Dennis (2020a), the first guiding principle is that language and dialogue create unity and simultaneity out of differences. The second principle is that all words, texts, genres, and disciplines integrate through semiotic or dialogic processes. As such, intertextuality, hypertextuality, and interdisciplinarity become metaphorical equivalents as contemporary appreciations of architectonics. The third principle recognizes Peircean semiotics or dialogism as a continuum on which intertextuality, hypertextuality, and interdisciplinarity serve as nodes and complementary ways to contemplate the creation and organization of knowledge in cognition and organizations. The last principle recognizes the importance of exigence, context, intertext, and hypertext in determining the proper approach and application of interdisciplinarity for studying the production and management of knowledge in education and the workplace using digital technology (Dennis, 2020a). To illustrate how architectonics and its related principles are operationalized in higher education, we can turn to the model of online education introduced by Anderson (2008). Not only does Anderson signify the value of an architectonic perspective in learning theory, but he also demonstrates what its modalities look like in terms of teaching and learning online.

Architectonics in Learning Theory

In his study of the relationship between pedagogy and technology, Anderson (2008) presents an interactive model of online education. *Online education* is the term that is used to describe teaching and learning using digital networks that are interconnected by the Internet and computerized devices (Picciano, 2019). Anderson (2008) contextualizes his understanding of online education and technology by first assessing how humans learn. To ground his understanding, he turns to the learning science presented by Bransford et al. (2000). The authors report that a central tenet of modern learning theory is that different learning goals warrant different instructional approaches. Anderson (2008) agrees with this insight. According to him, the work of these writers provides "evidence that effective learning environments are framed with the convergence of four overlapping lenses" (p. 47).

For Bransford et al. (2000), effective learning environments are community-, knowledge-, learner-, and assessment-centered. They use the term *community-centered* to refer to the various features that constitute a community and its contributions to the social nature of learning. This includes the school itself and the extent to which students, teachers, and academic leaders sense that they are connected to the greater community in which they live. Technological advancements actually help to initiate, develop, and sustain communal relations between these entities over time. One of the ways in which knowledge is constructed and reconstructed is through the social interactions that take place in the different contexts and environments in communities. Knowledge is always being transferred among communities, especially in schools. Schools are essentially the primary environments where we expect students to become knowledgeable. Knowledge-centered environments focus attention on the ways in which well-organized content is used to support planning and strategic instruction in education. They also focus on the particular kinds of information and learning activities that help students to understand academic disciplines. Different disciplines establish different worldviews that condition the ways in which knowledge is valued, discussed, and transferred. This may explain why Bransford et al. (2000) determined that knowledge-centered environments tend to emphasize sense-making along with disciplinary thinking. Sense-making or *framing* helps students to rationalize and negotiate the vast bodies of information that they encounter from one learning situation to the next.

The knowledge-centered environment often converges with learner-centered environments. This overlap is also evident when the teacher begins instruction by taking into account that the students may hold preconceptions about the subject matter being introduced. The learning-centered frame creates awareness of the importance of recognizing the particular cognitive preparation and understandings that students bring to the learning context. The teacher makes an effort to comprehend the student's prerequisite knowledge and preconceived notions. Appraising the worldviews and cultural practices that students bring to a learning situation ensures that the learning environment is conducive to their needs. This appraisal process is significant because it anticipates student assessment. An assessment-centered approach provides an opportunity for teachers to balance the use of formative and summative inquiries to determine what students have or have not learned. According to Bransford et al. (2000), these methods often generate the kind of feedback that motivates students and teachers.

Bransford et al. (2000) insist that the agency in the design of any learning environment rests on the interaction of all four frames of learning and not their compartmentalization. In other words, learning is recognized as an architectonic process that is sustained by words, texts, and contexts circulating in a system of reciprocity (also see Hawkins, 1994). For example, learning environments are leaner-centered when teachers build on the foundations that students bring to a learning context. However, learning environments are also knowledge-centered. In this sense, teachers must develop and organize academic content in ways that inaugurate and develop a student’s ability to comprehend and apply disciplinary knowledge. Bransford et al. (2000) report that, in order to determine the effectiveness of instructional processes and activities, the teacher must become assessment-centered. The results and feedback from assessment can lead to the kinds of improvements that are necessary for teachers to be more effective and students to be more successful. Ultimately, the triadic interactions between students, teachers, and content establish a classroom culture that values learning and strengthens the sense of connection that permeates the various communities in which knowledge is continuously constructed, activated, and transformed.

Architectonics in Online Education

With an understanding of effective learning environments as overlapping entities, Anderson (2008) gains the kind of interpretive lens that he needs to imagine how the various dimensions of learning converge in online education. Anderson (2008) suggests that the overlap among the four domains of effective learning mirrors the inherently interactive nature of technology and the Internet. For Anderson (2008), the unique characteristics and affordances of the Internet enhance the learning contexts and interrelations identified by Bransford et al. (2000). Picciano (2019) notes the significance of Anderson’s interpretative methods for advancing the idea that interaction and integration are critical components in the development of any theory of online education. He claims that the four frames of learning theory allow Anderson to detail the characteristics and accommodations that the Internet and technology permit with regard to teaching and learning in the classroom and particularly online. Picciano (2019) points out that Anderson also recognizes that these affordances are tied to the Internet’s evolution from a text-based environment to one that reflects the interactivity and interrelatedness of all forms of *hypertextuality* and *hypermedia*. Hypermedia expands “the notion of the text in hypertext by including visual information, sound, animation, and other forms of data” (Landow, 2006, p. 3).

Anderson (2008) would agree that hypertext and hypermedia are born of multi-sequential digital links and this networking capacity enables online education. As an architectonic enterprise, electronic links and digitalization interweave a variety of material across space and time. These digital networks also permit us to create, access, and/or follow multiple ideas and patterns in the same body of information on the Internet. They also trace one’s present and past endeavors as well as those of others

(Landow, 2006). In other words, digitalization inaugurates concurrence or *simultaneity*, one of the key properties of architectonic logic. Digitalization reminds us that simultaneity is also a feature of all synchronous interactions. This includes the digital networks that condition the various exchanges that Anderson (2008) describes in the processes that he associates with teaching and learning.

It is not surprising to find that reciprocity is recognized as a character in the description of interaction that Anderson (2008) privileges in his study of online education. He defines *interaction* as a reciprocal event that involves at least two objects and two actions. Interaction materializes out of the convergence of objects and events. Anderson (2008) admits, “It is surprisingly difficult to find a clear and precise definition of this multifaceted concept in the education literature” (p. 55). Nevertheless, the definition of interaction that Anderson (2008) settles on is significant because it frames and conditions his description of the six forms of interaction that he says play a critical role in engaging and supporting both teachers and students. In reviewing the six modes of interaction that Anderson (2008) imagines between students, teachers, and content, the reader will find more illustrations of Peirce’s triadic logic and the operationalization of intertextuality and hypertextuality.

For example, the six modes of interaction are student-student, student-content, student-teacher, teacher-content, teacher-teacher, and content-content interactions. Student-student interactions are characterized by peer-to-peer interactivities that allow students to investigate, understand, and develop multiple perspectives. Computer technology stimulates this collaborative process. According to Anderson (2008), collaborative work between students promotes cognitive development and the acquisition of critical social skills. More importantly, peer collaborations are essential for the development of effective communities of learning that allow students to evaluate knowledge shared by members of their community as well as formal curricula. When students, as individuals or collaborators, engage the knowledge that organizes and substantiates curricula, they are also participating in what Anderson (2008) calls student-content interactions. This form of interaction is a key component of formal education. However, the Internet makes this somewhat passive event more active for students.

Anderson (2008) notes that interactive content distributed via the Internet can be adapted to address the strengths and weaknesses of students. The customization of content for students provides opportunities for teachers to support the diverse learning needs of students. When this happens, student-content interactions are in concert with student-teacher interactions. Technology and the Internet support student-teacher interactions in a variety of ways. This includes both asynchronous and synchronous communications using a number of different formats, texts, and hyperlinks. Anderson (2008) claims that the flexibility that educational technology allows can offer students greater autonomy. Some of the authority that the teacher holds is distributed to students, allowing them to experience a degree of interdependence as individual and collaborative learners. To further increase student commitment and participation in learning, teachers might focus on the ways in which they negotiate and design learning activities and opportunities using academic content and other bodies of knowledge. Teacher-content interactions are not only ways to continuously monitor and develop course content, but they also inspire dialogue and learning among faculty members. The content that teachers design and distribute among students is often shared among fellow teachers in a particular subject area or across disciplines.

In many ways, teacher-teacher interactions promote a sense of community and support among faculty. These interactions also sustain professional growth and development initiatives that help to improve the overall quality of the teaching experiences for faculty and the learning experiences for students. Teacher-teacher interactions ultimately form the communities of learning that require students to navigate and negotiate the various academic content areas and discourses that they experience across the academy. Regardless of the academic discipline, content is always textual and interactive. Content-content interactions represent the last educational interactivity that Anderson (2008) describes. As a developing mode, content-content interactions allow disciplines and other bodies of knowledge to merge. Technology simply enhances and quickens these processes through hyperlinks. Advancements in educational technology can facilitate the tracking of content as it is used by teachers and students. It can also help us manage the augmentation and customization of content for individual learning needs. As content interacts with other content, the knowledge of students and teachers is constantly refreshed, expanded, and transformed. In architectonic thought, content-content interactions actualize the logic of *intertextuality*. Academic content is experienced as some form of text, and a text exists only because of exchanges with other texts. Barthes (1989) tells us that texts expand as an effect of combinative operations. As text, content is both the production and reproduction of knowledge. As such, content is an artefact of exchanges that simply model convergence and reciprocity in the learning process.

Anderson (2008) concludes that meaningful learning experiences occur when the appropriate educational interactions are located within the appropriate environments for learning. He claims, "The challenge for teachers and course developers working in an online learning context, therefore, is to construct a learning environment that is simultaneously learner-centered, content-centered, community-centered, and assessment-centered" (p. 66). He admits that there is no best way to design for these kinds of interrelationships, interactions, and outcomes. Anderson (2008) recommends that teachers develop "a repertoire of online learning activities that are adaptable to diverse contextual and student needs" (p. 66). This is exactly what Bernauer and Tomei (2015) attempt to help us to do when they introduce their integrated matrix—which acts as an architectonics of the competencies, learning objectives, and practices that faculty can use to maximize teaching and learning with technology in higher education. In their matrix, Bernauer and Tomei (2015) present the five quadrants that college faculty move through when learning how to use pedagogy and technology more effectively for teaching and learning. For example, the five quandrants are *apprentice integrator*, *pedagogical integrator*, *technological integrator*, *journeyman integrator*, and *master integrator*. The apprentice integrator is an educator who functions at the lower level of Bernauer and Tomei's matrix. Teachers who find themselves at this level typically lack sufficient experience as pedagogues and technologists, and they are often dependent on didactic activities, lectures, and textbooks. In the next quadrant is the pedagogical integrator. Those who operate in this part of the model are usually already skilled and successful instructors. However, they may lack the kind of experiences and abilities that allow them to maximize the use of educational technology in the classroom.

Unlike pedagogical integrators, technological integrators are able to activate the power of educational technologies and their many potentialities. The faculty members who work in this domain are usually more adept and comfortable using computer hardware, software, and related programs. However, they may overuse computers, the Internet, and other programs in order to engage students and relate course content. When instructors fall between the pedagogical and technological quadrants, Bernauer and Tomei (2015) call them *journeyman integrators*. These integrators tend to have a range of experiences and abilities in the areas of pedagogy and technology. Bernauer and Tomei claim that teachers operating in this quadrant are usually on their way to becoming master integrators. Master integrators are those who are at the pinnacle of Bernauer and Tomei's model. They have achieved a high degree of competence and vast experiences as pedagogues and technologists. Educators who reach this quadrant tend to have a library or *repertoire* of instructional methods and skills that they can adapt to meet the different learning needs of students. However, as Kirkwood and Price (2013) suggest above, even master integrators may be unable to identify the relevant theoretical ideas and frameworks that inform their views and practices. In a sense, Bernauer and Tomei (2015) substantiate this point when they report that "college faculty often have their own set of expectations and beliefs based in large measure on little more than how they were taught when they were students" (p. 5).

Conclusion

However, based on the synthesis of the disciplinary scholarship and perspectives above, Gazoni (2016) would agree that Peirce (1955) offers us the kind of compelling scholarly approach and interdisciplinary model that faculty can use to bridge the gap between theory and practice in SoTL. More specifically, Peirce's theory of signs and the interactivity among *firstness*, *secondness*, and *thirdness* serve as a cogent articulation of the ways in which convergence or intertextuality is operationalized in learning theory, online education, and teaching and learning with technology. With deep roots in the Western intellectual tradition, Peircean architectonics advances Boyer's innovation in SoTL, thus enriching our scholarly discourse and helping us to think and communicate across disciplinary boundaries in higher education. In turn, we are better able to reimagine our frameworks in relation to our diverse practices. Also, we can revalue the ways in which intertextuality, hypertextuality, and interdisciplinarity condition our understanding of the integrative capacities that operationalize teaching, learning, and technology. Hopefully, the agency located in architectonics and its coextending principles will renew interest in Boyer's (1990) work on the scholarship of integration as a continuous practice and important area of inquiry for future qualitative research in integrative learning and online education theory.

References

Alexander, B. (2020). *Academia next: The futures of higher education*. The Johns Hopkins University Press.

Anderson, T. (2008). Towards a theory of online learning. In T. Anderson (Ed.), *The theory and practice of online learning* (2nd ed., pp. 45–74). Athabasca University Press.

Bakhtin, M. (1990). *Art and answerability: Early philosophical essays by M. M. Bakhtin* (M. Holquist & V. Liapunov, Eds., V. Liapunov, Trans.). University of Texas Press.

Barthes, R. (1989). *The rustle of language* (R. Howard, Trans.). University of California Press.

Bernauer, J. A., & Tomei, L. A. (2015). *Integrating pedagogy and technology: Improving teaching and learning in higher education*. Rowman & Littlefield.

Boyer, E. L. (1987). *College: The undergraduate experience in America*. Harper & Row Publishers.

Boyer, E. L. (1990). *Scholarship reconsidered: Priorities of the professoriate*. Jossey-Bass.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school*. The National Academies Press.

Chandler, D. (2002). *Semiotics: The basics*. Routledge.

Chick, N. L. (2013). Difference, privilege, and power in the scholarship of teaching and learning: The value of humanities SOTL. In K. McKinney (Ed.). *The scholarship of teaching and learning: In and across the disciplines* (pp. 15–33). Indiana University Press.

Dennis, J. (2018). The intertextualist: Future teachers, past pedagogy, and dedifferentiation in multicultural education. *Journal of Interdisciplinary Studies in Education*, *7*(1), 78–86. https://doi.org/10.32674/jise.v7i1.1062

Dennis, J. (2020a). The Kantian effect: Reconceiving the integration of knowledge in interdisciplinary theory. *Journal of Interdisciplinary Sciences*, *4*(2), 1–14.

Dennis, J. (2020b). Languaging network learning: The emergence of connectivism in architectonic thought. *The International Review of Research in Open and Distributed Learning, 21*(3), 304–318. https://doi.org/10.19173/irrodl.v21i3.4718

Gazoni, R. M. (2016). Creative thinking in artificial intelligence: A Peircean account. In H. R. Arabnia, L. Deligiannidis, & M. Yang (Eds.), *2016 International Conference on Computational Science and Computational Intelligence (CSCI), Las Vegas, Nevada* (pp. 537–540). Institute of Electrical and Electronics Engineers.

Goffman, E. (1986). *Frame analysis: An essay on the organization of experience.* Northeastern University Press.

Foucault, M. (2010). *The archaeology of knowledge: And the discourse on language* (A. M. S. Sheridan, Trans.). Vintage Books.

Halliday, M. (1978). *Language as social semiotic: The social interpretation of language and meaning*. Edward Arnold.

Hawkins, D. (1994). Constructivism: Some history. In P. Fensham, R. Gunstone, & R. White (Eds.), *The content of science: A constructivist approach to its teaching and learning* (pp. 9-13). The Falmer Press.

Holquist, M. (1990). *Dialogism: Bakhtin and his world*. Routledge.

Hovestadt, L. (2010). *Beyond the grid: Architecture and information technology. Applications of a digital architectonic*. Birkhäuser.

Hovland, K., Anderson, C., & Ferren, A. (2015). Interrogating integrative learning. *Peer Review, 16/17* (4/1). https://www.aacu.org/peerreview/2014-2015/fall-winter/ferren

Huber, M. T., & Hutchings, P. (2004). *Integrative learning: Mapping the terrain. The academy in transition*. Association of American Colleges & Universities and The Carnegie Foundation for the Advancement of Teaching.

Huber, M. T., & Morreale, S. P. (Eds.). (2002). *Disciplinary styles in the scholarship of teaching and learning: Exploring common ground.* American Association for Higher Education and The Carnegie Foundation for the Advancement of Teaching.

Hutchings, P. (Ed.). (2000). *Opening lines: Approaches to the scholarship of teaching and learning.* The Carnegie Foundation for the Advancement of Teaching.

Hutchings, P., & Huber, M. T. (2008). Placing theory in the scholarship of teaching and learning. *Art & Humanities in Higher Education*, *7*(3), 229–244.

Kant, I. (2007). *Critique of pure reason* (N. K. Smith, Trans.). (Rev. ed.). Palgrave Macmillan. (Original work published 1787)

Kirkwood, A., & Price, L. (2013). Missing: Evidence of a scholarly approach to teaching and learning with technology in higher education. *Teaching in Higher Education, 18*(3), 327–337. https://doi.org/10.1080/13562517.2013.773419

Klein, J. T. (1996). *Crossing boundaries: Knowledge, disciplinarities, and interdisciplinarities*. University Press of Virginia.

Klein, J. T. (2005). Integrative learning and interdisciplinary studies. *Peer Review, 7*(4), 8–10.

Klein, J. T. (2010). *Creating interdisciplinary campus cultures: A model for strength and sustainability*. John Wiley & Sons.

Kristeva, J. (1986). *The Kristeva reader* (T. Moi, Ed.). Columbia University Press.

Landow, G. P. (2006). *Hypertext 3.0: Critical theory and new media in an era of globalization*. The Johns Hopkins University Press.

Lemke, J. L. (1992). Intertextuality and educational research. *Linguistics and Education, 4,* 257–267.

Lemke, J. L. (2002). Travels in hypermodality. *Visual Communications, 1*(3), 299–325.

Manchester, P. (2003). Kant's conception of architectonic in its historical context. *Journal of the History of Philosophy*, *41*(2), 187–207.

McKeon, R. (1987). *Rhetoric: Essays in invention and discovery* (M. Backman, Ed.). Ox Bow.

McKinney, K. (2007). *Enhancing learning through the scholarship of teaching and learning: The challenges and joys of juggling*. Anker Publishing/Jossey-Bass.

Nelson, T. H. (1987). *Computer lib/dream machine* (2nd ed.). Tempus Books/Microsoft Press.

Orr, M. (2003). *Intertextuality: Debates and contexts*. Polity.

Parker, K. A. (1998). *The continuity of Peirce's thought*. Vanderbilt University Press.

Peirce, C. S. (1887). Logical machines. *The American Journal of Psychology, 1*, 165–170.

Peirce, C. S. (1955). *Philosophical writings of Peirce* (J. Buchler, Ed.). Dover.

Picciano, A. (2019). *Online education: Foundations, planning, and pedagogy*. Routledge.

Schwab, K., & Malleret, T. (2020). *Covid-19: The great reset*. Forum Publishing.

Sharples, M., Taylor, J., & Vavoula, G. (2006). A theory of learning for the mobile age. In C. Haythornthwaite, R. Andrews, J. Fransman, & E. Meyers (Eds.). *The Sage handbook of e-learning research* (pp. 221–247). Sage.

Short, T. L. (2007). *Peirce's theory of signs*. Cambridge University Press.

Watson, W. (1993). *The architectonics of meaning: Foundations of the new pluralism*. The University of Chicago Press.

Webb, A. S., & Welsh, A. J. (2019). Phenomenology as a methodology for scholarship of teaching and learning research. *Teaching & Learning Inquiry, 7*(1), 168–181. https://doi.org/10.20343/teachlearninqu.7.1.11

Weimer, M. (2006). *Enhancing scholarly work on teaching and learning: Professional literature that makes a difference*. Jossey-Bass.

Werder, C. (2013). Navigating interdisciplinary riptides on the way to the scholarship of integrative learning. In K. McKinney (Ed.). *The scholarship of teaching and learning: In and across the disciplines* (pp. 240–252). Indiana University Press.

Witte, S. P. (1992). Context, text, intertext: Toward a constructivist semiotic of writing. *Written Communication*, *9*(2), 237–308.

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