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Editorial / Éditorial Volume 50 Issue 1

***Martha Cleveland-Innes**, Editor-in-Chief*

Welcome to Volume 50, Issue 1, of *The Canadian Journal of Learning and Technology* (CJLT). CJLT is a decades-old peer-reviewed journal that invites English or French submissions on the research and practice of education, technology, and learning. This bilingual journal is free-of-charge to anyone with access to the Internet, is multi-indexed, and presented in accessible formats. There are no article submission/publication fees or access charges.

CJLT's scope covers all things relevant to the improvement of education and technology use. This issue's Book Review is presented by Kyu Yun Lim, University of British Columbia, Canada about a book titled *Next level grammar for a digital age* by Darren Crovitz, Michelle D. Devereaux, and Clarice M. Morgan. According to Lim, "the book provides educators with a wide range of approaches to guide students in utilizing language in digital spaces and understanding rhetorical grammar to create digital content, aiming to raise learners to become more conscious digital readers and writers, and to grow up to be engaged citizens." I would add 'digital' to her last phrase and suggest these strategies will help student grow up to be engaged ***digital*** citizens. This notion prepares readers with a premise to consider when reviewing the research articles which follow.

While the book offers teacher development, Article 1 suggests that teacher training programs have not kept up with the necessary teacher development. *If You Choose Not to Decide: A Survey of Online Field Experiences for Canadian Teacher Preparation Programs/Si vous choisissez de ne pas décider : Une enquête sur les expériences de terrain en ligne pour les programmes Canadiens de préparation à l'enseignement* is presented by Jason P. Siko, Michael K. Barbour, Douglas Archibald, and Nathaniel Ostashewski. Their findings pinpoint the developmental lag between the use of online and distance learning opportunities and the teacher training programs available to K-12 teachers. Canadian teacher education programs with online or blended field experiences are in the minority. There is some evidence of "program offerings to support in-service teachers, such as graduate certificate, degree, and diploma programs, as well as MOOCs offering free professional development." This mixed-method replication study "found that programs were slow to change these deficiencies due to institutional lack of resources, limited knowledge base, perceived lack of usefulness for their teachers' future careers, and regulatory discouraging of online field experiences." This list is a valuable source for education leaders looking to remedy this notable deficiency.

While formal training remains scarce, research about online K-12 teaching practice is increasingly available. Nadia Delanoy, Jasmine El-Hacha, Monica Miller, and Barbara Brown present such research findings in Article 2: *Implementing a Flipped Learning Approach with TPACK in Grades 6 to 9/Mise en œuvre d'une approche d'apprentissage inversée avec TPACK de la 6e à la 9e année.* With practitioner-research approach, they "explore the implementation of a technology-enhanced pedagogy in science, math, and social studies." The TPACK framework provides teachers a way to understand technology, pedagogy, and content integration to design and teach effective online learning. In this case, TPACK was used "to inform the instructional design for the flipped learning activities" by providing online videos as pre-learning activities. Results indicate that, for teachers, the flipped classroom approach opened in-person class time to customize and personalize learning. For students, prior online video activities benefited overall learning and improved in-class learning activities. Recommendations are offered for teachers and schools implementing flipped learning.

Article 3 presents another type of technology integration: *Virtual Labs for Postsecondary General Education and Applied Science Courses: Faculty Perceptions/Laboratoires virtuels pour les cours de formation générale postsecondaire et de sciences appliquées : perceptions des professeurs* by Elena Chudaeva and Latifa Soliman. In this qualitative research, faculty member and learner perceptions of virtual labs are explored for usability, engagement, and accessibility. Findings derived from focus groups, surveys, meetings, and interview notes that, while five comprehensive themes emerge, "learners and faculty members may have different perceptions of the importance of virtual labs for the development of various skills." This is not surprising as the goals of each group are unique. Virtual labs are perceived as useful across groups, but faculty members' perceived barriers include a lack of digital literacy skills, technology training, and transition support. Recommendations about overcoming such barriers and virtual lab integration are included.

Generative Artificial Intelligence represents yet another major technology trigger that may have hit the peak of inflated expectations (King & Prasetyo, 2023). Most necessary now is the use empirical evidence about the education value of GenAI. For author Katja Fleischmann, "Generative Artificial Intelligence (GenAI) is re-defining the way higher education design is taught and learned." To explicate the students' view, she offers Article 4: *Generative Artificial Intelligence in Graphic Design Education: A Student Perspective/ L'intelligence artificielle générative dans l'enseignement du graphisme : Le point de vue d'un étudiant*. Her research "explores student attitudes toward GenAI, frequency of its use, and student perception of its impact on their future design careers." The results of this empirical study identify the critical role of educators to prepare critical, evaluative use of GenAI in their studio and professional practice. These early reviews of student GenAI use provide an evidence-based platform to guide educators and their students into the future.

Aïcha Benimmas and Margarida Romero created our French language article *Recréer le territoire de l'école par la cocréation de maquettes/Recreate the School's Territory by Co-Creating Models*. Here the researchers consider the relationship between education and community through a "process of co-creating their school district through the creation of a model combining analog and digital techniques."

In this experience, the learning uses multiple technological approaches that lead to levels of learning outcomes, based on the assumption that a learner's "relationship with space can be developed through a variety of learning activities." Through a software application and learning design, this creative research outlines ways to observe a learner's relationship with space and the demonstration of spatial thinking.

Our congratulations to all the authors!

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Next level grammar for a digital age: Teaching with social media and online tools for rhetorical understanding and critical creation. (2022).

Reviewed by ***Kyu Yun Lim****, University of British Columbia, Canada*

Abstract

Next level grammar for a digital age by Darren Crovitz, Michelle D. Devereaux, and Clarice M. Morgan has made a valuable contribution to English Language Arts (ELA) education by delineating how grammar instruction can be situated within real-life contexts using digital technologies and media, as well as emphasizing the importance of critical digital literacy in ELA education. The book provides educators with a wide range of approaches to guide students in utilizing language in digital spaces and understanding rhetorical grammar to create digital content, aiming to raise learners to become more conscious digital readers and writers, and to grow up to be engaged citizens. With its concrete and practical lesson ideas, the book helps language teachers to prepare for teaching complex and challenging topics that emerge in digital realms and to guide students to incrementally develop their literacy skills. Individuals in language education will find valuable insights for engaging discussions on how language teaching can be updated to meet requirements of an increasingly digital media landscape.

Introduction

Current communication modalities are mediated through digital media and technology. It is valuable to consider how teachers can integrate digital language into language classrooms. *Next level grammar for a digital age* by Darren Crovitz, Michelle D. Devereaux, and Clarice M. Morgan has made an interesting contribution to the field of English Language Arts (ELA). They describe how grammar instruction can be situated within real-life contexts using digital technologies/media and identify the importance of critical digital literacy in language education. With the widespread use of digital language, defined by the shift in linguistic features within digital spaces, the authors raise the following questions for educators: How can they best support learners navigating the complexities and challenges that the growing prevalence of digital realms bring, and how can they purposefully use language with digital tools?

While grammar instruction in language education should aim at empowering learners "to become better readers, writers, thinkers, and communicators" (p. 26), traditional approaches to grammar instruction often isolate lessons from real-world contexts, dedicating entire sessions solely to repetitive grammar practices. In teaching grammar, the authors' main objectives are twofold: first, to develop fluency in understanding the rhetoric of language use, and second, to foster critical digital literacy through grammar instruction, culminating in projects aimed at initiating social change and raising students to be more conscious digital readers and writers as well as engaged citizens. Therefore, Crovitz, Deveraux, and Morgan provide educators with a wide range of approaches to grammar instruction mediated by digital media and technologies. These approaches create a framework for guiding students in utilizing and accessing language in digital spaces and understanding rhetorical grammar to consume and create digital content.

The Landscape of Digital Language and The Necessity of Critical Digital Literacy

The authors begin the book by discussing how the advancement of digital technology and media has shaped and mediated our language use, and how the social contexts of digital language involve power and identity.

Today, youth employ various modes of expression in digital environments—blending emoticons, non-standard English forms, and hashtags into their texts. This linguistic playfulness and creativity in digital spaces contributes to effective communication and demonstrates their meta-knowledge of language. The authors advocate for embracing these digital linguistic idiosyncrasies within ELA classrooms, rejecting the dismissive "kids these days" (p. 4) mindset. They assert that integrating these digital linguistic practices will ultimately enhance adolescents' language skills and offer multimodal ways of delivering messages.

Despite these positive aspects of digital linguistic practices, the authors emphasize the necessity of critical digital literacy in navigating the digital landscapes. They define critical digital literacy as an inquiry into how language practices within digital spaces intricately intersect with power, culture, society, history, and identity. For instance, algorithm-driven design in social media fosters "silos of information" (p. 14) where individuals are exposed primarily to content that aligns with their pre-existing beliefs, potentially perpetuating misinformation and hindering democratic discourse. This underscores the importance of reading online content critically to facilitate informed decision-making and challenge entrenched power structures. Critical digital literacy also involves understanding how the use of language in digital spaces reflects our identities and social affiliations, raising concerns about authenticity. To combat these challenges, the authors advocate for teaching students to critically assess and produce digital texts, which requires teaching both critical digital literacy and rhetorical grammar.

Digitally Mediated Grammar Instruction

To offer examples about how to integrate grammatical instruction with critical digital practices, the authors present ten innovative classroom activities. These include creating one-minute animations illustrating how different sites, influencers, or companies use specific nouns to describe an issue trending online from different angles; describing their virtual reality experiences using adjectival phrases; crafting news reports solely using passive voice and recording podcasts to analyze the usage of passive voice in news reports; practicing the rhetorical use of colons and semicolons on platforms like

X(Twitter), which demand brevity; and experimenting with TikTok videos by writing comma-splice sentences to describe remixed content.

One of the outstanding examples on teaching grammar concepts is using memes. Crafting memes necessitates understanding how linguistic patterns and humor work together to achieve rhetorical purposes. Consequently, utilizing memes can help students grasp how grammar operates in practical contexts. The authors' multifaceted approach, which intertwines grammatical concepts with digital tools and platforms, harnesses students' engagement in digital writing to enhance their understanding of grammar in real-world situations.

Nevertheless, the integration of social media and digital tools into classroom activities is also accompanied by a cautionary note. For example, the provision of free online services often implies "we ourselves are the product" (p. 67). Our performance in social media such as clicks, likes, or shares produce data, which is analyzed and sold to organizations for targeted advertising and other purposes. Thus, the authors highlight the dual nature of our reliance on digital devices, which simultaneously holds the potential for both socially repressive uses and innovative affordances.

Moving Toward a Deeper Exploration of Critical Digital Literacy in Language Education

The authors delve into the nexus between language, power, and truth, arguing that discussions on grammar should ultimately involve "a discussion of power: how it's gained or lost, how it's maintained, how people use it in various ways, who has access to it and who doesn't, whose version of events matter." (p. 87). They further highlight the contemporary Internet landscape as a ground for propagating disinformation campaigns and conspiracy theories. In this account, the authors illustrate how syntactic strategies embedded in texts operate to deceive and provoke division and emphasize the importance of students cultivating a critical understanding of such tactics through focused grammatical analysis. For instance, their lesson ideas include dissecting language conventions of conspiracy theories and misinformation and analyzing the language moves of politicians.

Final chapters of the book are devoted to fostering counter narratives aimed at bringing about social change. They lead a profound discussion on linguistic and cultural appropriation in the digital world, contemplating the complexities and nuances of these issues. Showcased are various projects which employ language, rhetoric, and technology to drive social action and social change. This provides avenues to challenge dominant narratives and empower students to harness the transformative potential of digital realms. The examples involve a cyclical process guided by the National Writing Project (n.d.): identifying pertinent issues, understanding their underlying causes, brainstorming actionable solutions, implementing these actions, and reflecting upon their impact. They encompass a wide range of topics such as analyzing celebrities' social media usage to determine how they convey intentions, debunking misinformation, and designing multimodal campaigns to shift public perceptions. Included are initially structured tasks, driven by teachers, to more student-led initiatives, allowing students to identify and address social issues they recognize personally.

Throughout the book, the authors underline instances where digital artifacts can perpetuate linguistic or cultural appropriation. For instance, they discuss the phenomenon of "digital blackface", exemplified by exaggerated depiction of people of color in reaction GIFs (p. 74). The final chapter delves into the complexities of addressing linguistic and cultural appropriation within digital spaces, aiming to guide students in critically examining and evaluating whether certain practices reflect appreciation or appropriation. These discussions are integral to a broader exploration of identity, representation, and marginalized communities, constituting a challenging conversation. To cultivate critical analysis among students regarding digital artifacts like memes or remixed texts, the authors introduce the "Framework for Discussion" (p. 114). This framework, based on Tran (2016), can guide tough conversations and foster classroom discussions on these complex issues. The authors conclude that it is crucial for individuals to not only scrutinize the practices of others but also question their own practices to truly achieve social justice.

Conclusion

This book presents a wide range of pedagogical practices for English language arts teachers seeking to incorporate critical digital literacy into their classrooms. The most notable strength of this book lies in concrete and practical ideas that can be easily transferred to classrooms. Its exploration of recent, authentic societal issues, exemplified by events such as the murder of George Floyd, makes the learning experience more relevant for students. It also allows students to apply critical digital literacy to analyze, understand, and respond to real-life situations and helps teachers to prepare for teaching complex and challenging topics. Furthermore, the book integrates lesson plan ideas, spanning from individual grammatical concepts to comprehensive project-based approaches, to empower students to incrementally develop their digital reading and writing skills. While critical digital literacy practices have often been viewed separately from content instruction, this book effectively demonstrates their integration within language teaching. Additionally, it provides strategies for safeguarding students' online identities and privacy while leveraging social media as an educational tool by suggesting approaches like creating classroom Facebook pages or Instagram handles for student engagement.

One aspect that could enhance the book is the inclusion of the authors' insights from their real classroom experiences, given that the suggested classroom activities were implemented in secondary ELA classrooms. Incorporating details about students' reactions, conflicts arising from diverse viewpoints, and the challenges encountered while facilitating discussions would enrich the practical application of the provided lesson plan as well as equip educators with insights to navigate similar situations in their own classrooms. While the book predominantly addresses social issues within the context of the United States, adding global concerns would extend its relevance to a broader audience.

I highly recommend this book to individuals in language education, including researchers, preservice and inservice ELA teachers, teacher educators, as well as curriculum and textbook developers. Moreover, educators in the field of English as a Foreign Language or a Second Language will find valuable insights for engaging discussions on how language teaching can be situated within new and wider literacy practices.

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If You Choose Not to Decide: A Survey of Online Field Experiences for Canadian Teacher Preparation Programs

Si vous choisissez de ne pas prendre de décision : une enquête sur les expériences de terrain en ligne pour les programmes canadiens de préparation à l'enseignement

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Abstract

Despite the rapid growth in online and distance learning in Canada, there does not appear to be much interest on the part of teacher education programs to evolve to meet the needs of future generations of teacher candidates. While understanding the notion that systemic change in tertiary education takes time, the steady growth of online and blended learning in Canada–and globally–combined with raised awareness of distance learning stoked by the COVID-19 pandemic should make educators and policymakers worry about failing to respond to a rapidly changing educational landscape. This paper highlights the status of distance and online field experiences provided by Canadian teacher education programs. In addition, we review program offerings to support in-service teachers, such as graduate certificate, degree, and diploma programs, as well as MOOCs offering free professional development. This study, a replication of a mixed-method study originally conducted in the United States and published as a technical report by Archibald et al. (2020)[1], found that a minority of teacher education programs offered online or blended field experiences. Further, we found that programs were slow to change these deficiencies due to institutional lack of resources, limited knowledge base, perceived lack of usefulness for their teachers' future careers, and regulatory bodies discouraging online field experiences. This study highlights the dramatic need for programming in distance and online education.

Keywords: K-12 distance education, pre-service teacher preparation, teacher education

[1] This article is original, with some exceptions in the "Results" section.

Résumé

Malgré la croissance rapide de l'apprentissage en ligne et à distance au Canada, les programmes de formation des enseignants ne semblent pas suivre la tendance, ce qui permettrait de répondre aux besoins des futures générations d'enseignants et d'enseignantes. S'il est vrai que les changements structurels dans l'enseignement supérieur prennent du temps, la croissance constante de l'apprentissage en ligne et mixte au Canada et dans le monde, conjuguée à la prise de conscience de l'importance de l'apprentissage à distance suscitée par la pandémie de COVID-19, devrait sonner l'alarme auprès des éducateurs et des décideurs relativement au fait qu'ils n'arrivent pas à répondre aux besoins d'un secteur qui évolue rapidement. Cet article fait le point sur les expériences pratiques à distance et en ligne proposées par les programmes canadiens de formation des enseignants. Nous passons en revue les programmes destinés à accompagner les enseignants en exercice, tels que les programmes de certificat, d'études supérieures et menant à un diplôme, ainsi que les MOOC, qui offrent un perfectionnement professionnel gratuit. La présente étude, qui reproduit une étude à méthode mixte menée à l'origine aux États-Unis et publiée sous forme de rapport technique par Archibald et al. (2020), a révélé qu'une minorité de programmes de formation des enseignants offraient des expériences pratiques en ligne ou mixtes. Par ailleurs, nous avons constaté que les programmes ne remédiaient que lentement à ces lacunes en raison d'un manque de ressources institutionnelles, d'une base de connaissances limitée, de la faible utilité que les futurs enseignants et les organismes de réglementation leur accordaient, ce qui décourage les expériences de terrain en ligne. Cette étude met en évidence le besoin considérable de programmes dans le domaine de l'enseignement à distance et en ligne.

Mots-clés : enseignement à distance de la maternelle à la 12^{e} année, formation initiale des enseignants, formation des enseignants

Introduction

Distance, online, and blended learning[2] have become an integral part of the educational options at many higher education institutions and in many K-12 schools. Large-scale surveys in the United States (US) have shown the consistent growth of online education at all levels (see Allen & Seaman, 2013; Seaman et al., 2018). Within the Canadian context, the number of K-12 students engaged in distance, online, and blended learning in Canada has also increased significantly. In the past decade and a half, the number of Canadian students enrolled in distance and online programs grew from less than 140,000 students in the 2008-2009 school year to more than 360,000 students in the 2022-2023 school year (Barbour & LaBonte, 2023). The estimated gains in enrolment have been even more dramatic for blended courses. While the K-12 digital learning data from the US is more difficult to quantify, the latest *Snapshot* report from the Digital Learning Collaborative (2024) states that "it is clear that the pandemic greatly increased digital learning activity temporarily—even beyond emergency remote learning. It is also clear that only some of that increase has been sustained" (p. 1).

[2] There is little agreement on terminology within the broader field of K-12 distance, online, blended, hybrid, and/or flexible learning (Barbour, 2019). In this manuscript we used the term(s) used by the authors themselves, and in instances where the decision was ours, we have used K-12 distance, online, and blended learning as a generic term to refer to broader activity in the field.

This reported growth discounts the reality that the educational world was turned upside down by the COVID-19 pandemic. Within weeks, schools had to pivot from traditional methods to a mix of online and correspondence methods referred to as “emergency remote learning” (Barbour et al., 2020; Hodges et al., 2020). Arguably every teacher and student across the country unfamiliar with online and blended learning experienced pressure to massively overhaul their teaching practices at the end of the 2019-2020 academic year, which for many continued during the 2020-2021 school year. Despite decades of growth, the pandemic exposed how unprepared and unfamiliar the majority of the K-12 ecosystem was when it came to online learning. While the initial switch to remote teaching was a patchwork endeavour, where student learning was understandably affected, effective online teaching the following year could not be achieved with a few summer workshops.

As we emerge from the pandemic, there is a desire to return to pre-pandemic ways and means, and, for many, online learning is not something that they will miss. However, the trajectory of online growth will resume, and so will the need for teachers who are better equipped to teach in this medium. Hodges et al. (2022) described a vision and multi-step plan for meeting this need. These steps involved proper financial support of research initiatives to create effective methodologies and guidelines that could be implemented and assessed in teacher training programs, as well as preparing educators for virtual instruction by offering hands-on experience in crafting, presenting, and guiding online lessons – ideally while forcing them to participate as students in online learning environments themselves. The authors recommended embedding online experiences for pre-service teachers (i.e., those individuals engaged in a teacher education program prior to beginning their career as a teacher, as opposed to in-service teachers who have completed their initial teacher training) including taking online courses and participating in field experiences. In addition, they advocated for the adoption of research-based online teaching standards and metrics for measuring growth with these standards. Their vision culminated with the addition of online learning experiences as a requirement for accreditation of a teacher preparation program.

In the US, finding online field experiences is rare. Kennedy and Archambault (2012a) found that only 1.3% of US teacher education programs were preparing pre-service teachers for online learning by providing field experiences in virtual schools. A follow-up study five years later found that that figure had increased to 4.1% of the responding teacher education programs (Archambault et al., 2016). The purpose of this study was to identify and describe the status of Canadian teacher education (i.e., pre-service and in-service) and their associated field experiences in K-12 distance, online, and blended learning prior to the pandemic. Using a mixed-methodology approach, survey data were collected that describes the state of field experiences based on responses from deans and directors of education faculties across Canada. This research will add a Canadian perspective to this American-focused literature to date (e.g., Archambault, 2011; Ferdig & Kennedy, 2014; Kennedy & Archambault, 2012a) by describing teacher preparation for K-12 online and blended learning environments and providing a much-needed snapshot of the Canadian context.

Literature Review

Teaching in online and blended environments are, on one hand, similar to traditional in-person teaching. On the other hand, it seems intuitive that one would require a set of specific skills for teaching students when you rarely see them in person, if ever. The differences between in-person and online teaching became apparent in March 2020 when schools suddenly switched to online learning, and that shift was clearly not fluid (i.e., if online and in-person teaching required the same skills, the transition would not have wreaked havoc with respect to learning loss, student and teacher stress, etc., on Canada's K-12 system – see Barbour & LaBonte, 2020; LaBonte et al., 2021; 2022; Nagle et al., 2020a; 2020b; 2021).

The problem faced is in identifying those specific skills. For example, online teachers may need to master asynchronous communication skills without ever interacting with their students face-to-face (Friend & Johnston, 2005). They will likely need to combat the feelings of isolation students have when they work through a course alone and establish an online environment where students feel comfortable asking questions (Barbour et al., 2013). Online teachers also need to foster a culture of meaningful online interactions between the students on discussion boards and group assignments and ensure students stay on task. These may be foreign situations to new teachers, and the keys to navigating them successfully are not always evident. Polly et al. (2023) surveyed pre-service and in-service teachers on their perceived usefulness of and competencies with digital tools and found that both groups consistently listed learning management systems and collaborative tools – perhaps the most ubiquitous tools in online teaching – as the most important tools. In addition, Polly et al. found that pre-service teachers rated their competencies higher than their in-service counterparts. The authors posited that their lack of experience in classrooms may have led to overly optimistic views of their capabilities. However, Moore-Adams et al. (2016), in their literature review of K-12 teacher preparation for online teaching, found a deficit of empirical research on the topic. They identified competencies based on the TPACK framework (Koehler & Mishra, 2009), but prefaced their findings with caution since the research reviewed was so varied. Finally, while research in online learning has grown, in their systematic review of online research this century, Martin et al. (2023) found that only about eight percent of journal articles focused on teacher preparation and professional development.

Despite being dated with respect to the advancements in platforms, services, and bandwidth, early empirical work in teacher preparation for online learning provided a blueprint for future studies. Researchers at Iowa State University first developed a set of 10 case studies highlighting exemplary course development as part of a project entitled *Good Practice to Inform Iowa Learning Online* (Davis & Roblyer, 2005). The follow-up to this project, *Teacher Education Goes Into Virtual Schooling*, was positioned to introduce pre-service educators to virtual schooling and the idea of the three different adult roles in online teaching (some of which could be served by the same person): the online teacher, the online course designer, and the in-person facilitator who acts as a liaison between the student and teacher (Davis et al., 2007). With respect to actual field experiences, there are examples for both pre-service and in-service teachers. The University of Central Florida paired with their state virtual school to provide teacher candidates with the opportunity to have a field experience in a virtual setting. Further, both Arizona State University and Wayne State University—as well as others—created graduate certificates that included virtual field experiences (see Kennedy & Archambault, 2012b; 2013). This seminal work paved the way for improvements in teacher preparation.

Once these distinct skills have been identified, the next logical step is to figure out how to incorporate them into teacher preparation programs. Hodges et al. (2022) listed six events that should occur to better prepare teachers for teaching online. First, a set of research-based online teaching standards needs to be universally adopted. While several collections of online teaching standards exist, they lack the backing of empirical research (Adelstein & Barbour, 2016). Second, validated instruments are needed to ensure that standards are being met (Barbour, 2020). Third, students need to have more experiences as online students to better understand and empathize with their future students (Zucker & Kozma, 2003). While there is a generation of students who experienced remote teaching during the pandemic, a specific experience should be codified in teacher preparation programs. Fourth, teacher candidates should have specific training in teaching online, much like the advent of standalone technology courses as technology became more ubiquitous in classrooms (Irvine et al., 2003). Fifth, teacher candidates need to have online field experiences (Davis & Rose, 2007). Finally, accrediting bodies need to include online learning preparation in their standards (Gedak et al., 2023). To be clear, the authors noted the significant barriers to implementing these steps, most notably the already lengthy teacher preparation process.

Canada's efforts to prepare pre-service teachers for teaching online mirror those in the US. Many teacher education programs embed content on online learning in their standalone educational technology course (Barbour, 2012). They also struggle with the same barriers that Hodges et al. (2022) mentioned, namely the absence of empirically-based strategies (Barbour et al., 2013), and direction from the provincial and territorial governments in the form of standards and mandates (Barbour & LaBonte, 2017). Several exemplars of online teaching preparation include Queen's University, which changed its standalone information and communications technology course to focus heavily on online teaching pedagogy (Barbour et al., 2013), and Memorial University, which housed the Centre for Telelearning and Distance Education from 1999 to 2004 that was home to an undergraduate program that focused on rural education through distance learning (Barbour, 2012), and later the Killick Centre for E-Learning Research to study K-12 online learning across Canada (Faculty of Education at Memorial University of Newfoundland, 2011). Moreover, these programs addressed a preparation need for pre-service teachers, who may or may not have an interest in learning about online pedagogy on top of their other preparation requirements. However, they did not address the need to prepare in-service teachers.

In much the same way that the US has attempted to address training in online teaching (Kennedy & Archambault, 2013), there are several instances of professional development opportunities for in-service teachers through graduate degree and certificate programs described in the literature. Graduate certificates in online teaching were offered at Thompson Rivers University and Royal Roads University (Harrison, 2012), or in the case of Ontario training associated with the Additional Qualification for Teaching and Learning through eLearning (Smith, 2012). Athabasca University offered a broad suite of options, including graduate certificates as well as master's and doctoral programs (Barbour, 2012). Further, Athabasca University took content from their graduate programs and created modular teacher professional development opportunities and massive open online courses (MOOCs) (Blomgren, 2017;

2018). Thus, opportunities existed for all current and prospective teachers to gain knowledge regarding online teaching, albeit on a small scale overall.

Last, there is a growing body of literature on teacher preparation and in-service professional development during the COVID-19 pandemic that is focused on policy changes and reimagining teacher preparation. Van Nuland et al. (2020) described the challenges teacher education faced when schools moved to remote teaching, namely, how to account for lost field experience time and lack of face-to-face interaction, in addition to having pre-service teachers adjust to online learning themselves (i.e., as their traditional coursework moved online as well). Additionally, Johnson (2023) reported that many higher education faculty were challenged with effective online instruction, which further exacerbated the problem. Hill et al. (2020) took this one step further, acknowledging the need to overhaul teacher education to address the needs of students that were highlighted during the pandemic, such as mental health, anti-racism, and equity issues. Farhadi and Winton (2021) conducted focus groups with educational personnel in Alberta and concluded that the pandemic served as a tipping point for many issues with education in general, such as those related to funding, class sizes, and teacher compensation. With respect to teaching online, even those with advanced coursework in educational technology lacked the efficacy under the duress of the issues to teach remotely.

Finally, Woo et al. (2023), in their systematic review of online teacher preparation research, highlighted the evolution of field experience over the past 20 years, especially during the pandemic. The authors stated that while the pandemic created more challenges for the field experience, it also created more opportunities. The pandemic exposed additional issues of isolation for both teachers and students, which signaled a need for teacher preparation programs to teach teacher candidates about building relationships. While teacher candidates generally expressed unhappiness over the restrictions during the pandemic, they came to appreciate the opportunities these restrictions presented to discover new technologies and techniques for instruction. The authors suggested that with the uptick in research on teacher preparation during the pandemic, institutions should now apply those insights when making changes to the preparation process. Examples included preparing candidates for short-term adaptations (i.e., in the face of another pandemic or climate disasters), shorter field experiences in different situations rather than an online experience in addition to a traditional field experience, and further integration of the technology and instructional design into the field experience rather than the traditional standalone technology course. These findings were echoed in the Canadian context by Gedak et al. (2023), who explored how the regulations regarding teacher education in Canada prevented teacher preparation programs from implementing the kinds of experiences that Woo and colleagues (2023) recommended. Al-Ansi (2022) suggested that many of these online tools and strategies will continue to be used by teachers post-pandemic; addressing the issue of preparing teachers to teach online will hopefully be part of a larger overhaul of the teacher preparation and professional learning processes.

To summarize, while research into online teaching and learning has grown, teacher preparation continues to lag in preparing future and current educators for this medium. The pandemic made this deficit apparent and now provides an opportunity to consider how teacher educators and policymakers can adjust programs to improve instruction online, whether it is due to the continued growth in K-12 online learning or the next catastrophe that again forces students to learn remotely. This paper serves as a first step in the process, a snapshot of what Canada offers with respect to teacher preparation for teaching online.

Methodology

The purpose of this study was to replicate a mixed-methods study originally conducted in the US to examine the provision and support of K-12 e-learning field experiences in teacher education programs (Archambault et al., 2016; Kennedy & Archambault, 2012a). As a mixed-methodology approach with an embedded design, participants were asked to respond to both quantitative and qualitative questions in the survey (Creswell, 2014). In this case, the focus of the embedded design was the quantitative questions which informed about how widespread the adoption of field experiences was at different kinds of institutions in different places. However, the qualitative responses were necessary to flesh out the rationale regarding why faculty and administrators either embraced or avoided offering the field experiences as well as to understand the nature of the field experiences offered.

The assessment instrument used was adapted from one used in a similar study in the US (see Archibald et al., 2020), to adjust for the unique aspects of higher education in Canada and any other cultural differences. The survey was then loaded into a web-based questionnaire format that consisted of 31 questions (i.e., 27 quantitative questions and 4 qualitative questions). Potential participants were identified by a search for the Dean or Director of the Faculty of Education on Faculty of Education websites at each Canadian university and college. A total of 72 potential participants were found at 67 institutions (see Archibald et al., 2020 for a complete list of institutions).

Each of the respondents was sent an email describing the study and requesting that they complete the survey, followed by six reminders over the next seven weeks. Of the 72 individuals contacted, 32 responses were received from 30 different institutions, representing a 42% response rate, which is considered acceptable for web-based instruments (Manfreda et al., 2008; Shih & Fan, 2008). In comparison, Kennedy and Archambault (2012a) reported a 34% response rate, while Archambault et al. (2016) indicated a 37% response rate. It should be noted that Fan and Yan (2010) suggested that online surveys generally have an 11% lower response rate than surveys conducted in other mediums.

We acknowledge that the data in this study was collected prior to the 2020 pandemic. However, at the end of the 2019-20 school year, teachers were forced to manage emergency home-based or remote teaching, and many continued to teach in a remote and/or hybrid fashion throughout the 2020-21 and 2021-22 school years.[3] Given these realities, the results of this study are an important assessment of how well those individuals were formally prepared by their teacher education programs to meet the challenge of designing and/or curating, delivering and/or facilitating, and supporting e-learning experiences for their students.

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[3] See Canadian eLearning Network's Pandemic Pedagogy Research (https://sites.google.com/view/canelearn-ert/) for more information.

The data were analyzed by first connecting the location, institution, and background information to the corresponding responses. We were then able to build a picture or case of how different institutions in different locations ran their online and blended pre-service and in-service field experiences (Monk & Howard, 1998). Next, descriptive statistics were used to create simple summaries of the key features of those field experiences (Mishra et al., 2019), and were compared to other experiences to find similarities. Finally, we looked at the reasons for the different programs having or not having and wanting or not wanting a pre-service or in-service program. Respondents' answers often shared common reasoning, and therefore these were able to be categorized into two to four themes. Some responses however corresponded to multiple trends of reasoning, and so those were counted as responses in each trend they referenced. Finally, these trends in Canadian programs' reasoning were compared to the US trends (Archambault et al. 2016; Kennedy & Archambault, 2012a).

Results

As this study represented a "current state" of teacher education and K-12 virtual field experiences across Canada, and we anticipated the dissemination of this study to be of significant value to participants and their institutions, efforts were made to compile as complete a picture as possible from the sample participants.

Respondent Description

A total of 25 out of the 30 respondents indicated their locations, representing all but four provinces and territories (i.e., Nova Scotia, Prince Edward Island, the Yukon, and the Northwest Territories). As might be expected, Ontario (n=10) and British Columbia (n=5) had the highest number of responses. Almost half of university survey respondents were from small institutions (i.e., less than 2,000 students), with a third of respondents representing medium-sized institutions (i.e., between 5,000 and 20,000 students), and a fifth of responses from large institutions (i.e., more than 20,000 students). Finally, the most represented group in terms of the individual completing the survey were placement coordinators (43.8%), followed by faculty (37.5%), coordinators (15.6%), and finally deans (3.1%).

State of Programs with Field Experiences

When asked whether their institution offered field experiences in K-12 online program settings (e.g., guided observations, internships, or apprenticeships) for pre-service or in-service teachers, only 8 out of the 17 respondents indicated that they did – although based on additional questions it appears that these were more focused on blended learning field experiences. One school, from Quebec, also mentioned that through their elementary school partnership, around 200 teachers were annually placed in blended field experiences. Interestingly, two of these eight respondents suggested that the online or blended field experience was a requirement for their institution's teaching degree, and one indicated that it was a requirement for teacher licensure in their province. Only one respondent stated there was a specific time requirement regarding online or blended learning during the field experience, stating that teachers were required to spend four to eight hours a week for four to eight weeks engaged in creating new online course content, evaluating students' work, filling out paperwork, and attending professional development sessions. Finally, a respondent from New Brunswick described how their program places about a dozen teachers in a blended elementary field experience specific to teaching in First Nation classrooms.

Reasons Programs Do Not Want to Have Online Field Experiences

It is important to underscore that many institutions (55.6%) did not offer field experiences in K-12 online and blended environments to pre-service teachers. Although reasons varied, respondents reported that the main reason was a lack of resources such as funding, management, or human resources needed for student evaluation. The next reason was that the respondents did not currently know enough about these experiences to include them. A respondent from Saskatchewan stated:

> We do provide extensive instruction to students in using digital media and teaching in on-line learning contexts, but as of yet, have not attached a formal internship experience to this, partly because we have not yet fully explored what these possibilities might look like in Saskatchewan.

The third reason provided was that online field experiences had limited usefulness to pre-service teachers' future careers. As an example, one respondent from Ontario simply stated, "at this point in time, there are insufficient career paths to make this a viable alternative to face-to-face field experiences." It is noteworthy that this data were collected only a short time before teachers would be forced to teach remotely due to a global pandemic. A final explanation for not being able to implement online field experiences had to do with their province's Ministry of Education or teacher union regulations or standards.

Reasons Programs Want to Have Online Field Experiences

There were a variety of reasons why some institutions wanted to have an option for students to undertake an online field experience. Increased access was the most popular reason for being in favour of having online field experiences. A respondent from Manitoba mentioned issues with students in remote locations:

> I am largely saying yes since it sounds like a potentially interesting concept particularly for our 'distant education' students or the potential to offer up field experience and programming to our Northern Educators who struggle with commuting to the Institution for spring & summer sessions in order to gain their degree and certification - currently regular session (fall & winter) is really not an option for them because of distance.

Increased flexibility was the other reason respondents were in favour of implementing online field experiences. A respondent from Saskatchewan discussed how it should be an option for pre-service teachers who are interested/specializing in teaching in online settings. Given Canada's size and remote areas that have issues with access, institutions that service these areas would benefit from such an expansion.

Future Plans for Online Field Experiences

Less than 20% of institutions responded that their teacher education program is in the process of designing online field experiences for pre-service and in-service teachers. The respondent from New Brunswick that shared their work with First Nation schools stated their interest in replicating their efforts with their traditional teacher preparation program. However, it appeared that these plans were in their infancy. For example, a respondent from Saskatchewan stated, "not sure yet. It will use cooperating teachers across the province but with technology to deliver and collect content."

Discussion

As the results reported by Archibald et al. (2020) were generated using an instrument that had been used in two earlier studies in the US, it is both useful and instructive to compare the data from both countries. This is followed by a consideration of the Canadian data reflecting the broader field.

In Comparison to the US-Based Studies

Archibald et al. (2020) found that 8 of 17 Canadian institutions reported offering field experiences in K-12 online settings for teachers, though these experiences primarily focused on blended learning rather than on actual online environments. Both US studies provided a caveat to their data on schools having an online field experience (Archambault et al, 2016; Kennedy & Archambault, 2012a). These studies reported two numbers: the number of institutions that stated they had an online field experience and the number of institutions that provided evidence. In both cases, the latter number of institutions that shared about their programs was much lower. Since eight (32%) of our respondents provided additional information, that number was used as a basis for comparison. In both the 2012 and the 2016 US studies, the percentage of institutions that responded in the affirmative and provided evidence were 1.3% and 4.1%, respectively (Archambault et al., 2016; Kennedy & Archambault, 2012a).

Most Canadian institutions did not offer online field experiences for pre-service teachers, citing reasons such as lack of resources, insufficient knowledge, perceived limited usefulness, and regulatory constraints (Archibald et al., 2020). Similar to what Kennedy and Archambault (2012a) found, a key reason for not providing an online field experience was that respondents valued face-to-face teaching experiences more and did not want to divert resources from those experiences. Additionally, many of the US respondents were under the impression that face-to-face skills were easily transferred to the online environment. The US respondents also expressed regulatory concerns from their state boards of education. Finally, US respondents were unsure of the usefulness of the online field placement option since most teachers were likely not going into the field to exclusively teach online and therefore, post-baccalaureate training would suffice.

Archibald et al. (2020) also reported that Canadian institutions who favoured online field experiences cited increased access and flexibility as key advantages, particularly for students in remote locations or those specializing in online teaching. In the US study (Kennedy & Archambault, 2012a), those with favourable opinions of online field experiences cited slightly different reasons, emphasizing the need to address the pedagogical differences in online and traditional learning. With that said, the US responses tended to be more pragmatic in nature, where comments centred on vague notions of future needs [e.g., wave of the future, it is coming, so we need to (Archambault et al., 2016)]. Not much was said about access to education in remote areas.

Finally, only a small minority of institutions were in the early stages of designing online field experiences for teachers, with plans still largely undefined (Archibald et al., 2020). Both US studies (Archambault et al, 2016; Kennedy & Archambault, 2012a) provided little data on future plans, and in general, reported similarly vague notions of the future. The authors lamented that perhaps survey respondents were unclear on terminology, as evidenced by multiple "don't know/unsure" responses. While it may have been more acceptable to be unaware of the nuance with online teaching during the time the studies were conducted, that is less likely now. On the other hand, the lexicon has changed, and terms like hybrid learning, blended learning, and remote teaching have nuanced definitions that many outside the field rarely understand. As such, while using the same survey allows for better comparisons, an updated or revised survey may be necessary. Interestingly, the authors did mention several instances of the survey itself being a potential impetus for exploration.

The nature of the respondents in each of the three studies was consistent. For example, all three studies reported receiving the largest percentage of respondents from institutions that had fewer than 5,000 students (Archambault et al, 2016; Archibald et al., 2020; Kennedy & Archambault, 2012a). However, given the size differences between the two countries, further comparisons in number and size of institutions are not useful. While both US studies had placement coordinators as the largest percentage of respondents (Archambault et al, 2016; Kennedy & Archambault, 2012a), Archibald et al. (2020) had comparatively fewer administrators respond (i.e., 33% in the US study versus 3%); otherwise, the remaining categories were aligned.

The results of the Archibald et al. (2020) Canadian study provided additional insight on the current state of online teacher preparation when compared to the studies in the US. Data from the two countries were similar in many respects. Reasons against institutions not having an online field experience included deficiencies in resources, knowledge, and perceived demand. The reasons for them having this type of field experience reflected slight differences between the two countries. Canada's reasons emphasized access to education for remote areas, while the US reasons were more generic, centring on the inevitability of technological progress. However, respondents from both countries noted that training for online learning should look different from training for traditional teaching.

Within the Broader Context of Teacher Education

Beyond the comparisons of what was found in the Canadian context in relation to the earlier studies in the US, given the current realities with respect to increase frequencies of pandemic/endemic diseases and severe weather due to climatic change, school systems will likely need to close for significant periods again in the future. Although it may be more localized than what was experienced with COVID-19, and the duration may be much less, school systems will likely need to close again, and teachers need to be prepared to provide learning at a distance. As such, it is important to explore these results through the lens of Hodges et al. (2022). When doing so, one could see a difficult but not impossible path to making online field experiences the norm rather than the exception. Research-based online teaching standards, or the lack thereof (Adelstein & Barbour, 2016), present a challenge due to inertia (i.e., there needs to be a willingness for researchers and institutions to design and develop standards and support with research). In addition, Adelstein and Barbour suggested that after standards are developed, they would need validated instruments to see if the standards are being met. Again, this would require buy-in from institutions and provincial governments for support and implementation. With the increase in online learning research from the pandemic, as Woo et al. (2023) have noted, the empirical support should be gaining traction. As well, standards would need institutional and provincial support (Barbour & LaBonte, 2017), and the data reported in this study has clearly shown a lack of interest – at least immediately before the start of the pandemic. We found that a minority (32%) of the respondents' programs had online or blended field experiences for their pre-service and in-service teachers. Surprisingly, none of those field experiences were newer than five years old (i.e., they were all established prior to 2012). It appeared that rather than the field experiences in these programs being motivated specifically to prepare teachers for the current challenge of online and blended learning environments, they were formed by necessity due to the high quantity, the remoteness, or the tight schedules of the teachers enrolled.

Respondents who did not have online field experiences and had no plans to change listed four general reasons: lack of resources, lack of knowledge, lack of value (i.e., utility), and current regulations. As both Woo et al. (2023) and Gedak et al. (2023) noted, the pandemic provided a wealth of experiences that could shift some of these opinions. For example, respondents felt that online field experiences were not useful for future careers. Post-pandemic, perhaps the respondents – with increased experiences – would now feel differently. With respect to resources, both K-12 and higher education shifted resources toward online learning. These resources (e.g., cameras, microphones, learning management systems), many of which are physical, are still available for use. Put differently, some of the costs associated with startup are no longer needed, and additional resources need only be spent on replacement and license renewal.

The third step Hodges et al. (2022) suggested was to expose teacher candidates to more online and blended experiences as students. Even before the pandemic, the number of students in online environments doubled in the last decade, and the number of students in blended environments has almost doubled in the previous three years (Barbour & LaBonte, 2019). Because of this increase, it would require little effort by institutions to guarantee this exposure by ensuring that every teacher candidate take some amount of coursework online. Having education faculty trained in online teaching practices would not only support this step, but possibly the next step as well.

The fourth step, requiring teacher candidates to have specific training in teaching online, is again hampered by the lack of standards. As Moore-Adams et al. (2016) argued years before the advent of COVID-19 and the associated school closures and rapid transition to remote learning, a clearly defined set of skills specific to teaching online is needed to justify a course (or content within a methods course) dedicated to this topic. Respondents also listed a lack of knowledge as a barrier to online field experiences, as well as resources. With respect to resources, respondents believed that any online endeavour comes at the expense of face-to-face requirements. A standalone course would be an additional course on an already full curriculum. On the other hand, incorporating online teaching into current coursework would require the instructors of non-educational technology courses to become fluent in online teaching pedagogy, and Johnson's (2023) research reported that faculty find it difficult to teach online effectively. Another area for improvement would be more empirical research on online teaching at the teacher preparation level, as Martin et al. (2023) found this to be an area where research was relatively scarce.

The fifth step, requiring online field experiences in teacher preparation programs, was the centrepiece of this study. One-third of respondents claimed to offer some online field experience, and these were well-established. Further, of those programs that did not have any online field experiences, 55.6% also believed that they should not provide them in the near future. Reasons for not providing online field experiences included the sentiment that they would not help pre-service teachers get a job, or they simply did not know enough about them. However, post-pandemic, employers may see these skills as an asset regardless of whether teachers are in-person or remote. As Woo et al. (2023) noted, relationship building was key to successful online teaching; it is also key to traditional instruction.

Finally, Hodges et al. (2022) stated that the final step would include tying online field experiences to accreditation. Once again, this can only be done after the previous five steps are in motion. Respondents stated that regulations from both the ministry and the union were barriers to implementation. Stakeholder negotiations would need to take place in order to codify online teaching into preparation programs. It is likely that this would only occur as a result of a nationwide modernization effort for teacher education and professional learning (Al-Ansi, 2022; Farhadi & Winton, 2020; Hill et al., 2020).

Overall, the survey results indicate a stagnation in the progress toward making online field experiences a key component of preparing Canadian educators. Further, respondents provided little information regarding any efforts toward professional learning for in-service teachers, as none of the respondents were associated with institutions previously discussed in the literature review (Barbour, 2012; Blomgren, 2017; Harrison, 2012; Smith, 2012). However, given the similarities between this study and the studies on which it was modeled (Archambault et al, 2016; Kennedy & Archambault, 2012a), and given that the data were collected prior to the COVID-19 pandemic, there should be optimism that change is possible. Stakeholders and policymakers could potentially use the blueprint provided by Hodges et al. (2022) to make the necessary changes.

Conclusions and Implications

In this study, we examined the current state of online field experiences in Canadian teacher preparation programs, replicating a series of studies conducted in the US. Much like Canada's southern neighbors, the adoption of online field experiences has not kept pace with the demand for online instruction at the K-12 level (Barbour et al., 2020). While data for this study were conducted before the COVID-19 pandemic, it still provides a snapshot of the landscape, as any full-scale changes made post-pandemic are likely still in the planning stages.

To have widespread incorporation of online field experiences, teacher education programs and their faculty can do several things. As researchers, faculty can follow lines of inquiry that help to validate online teaching standards and instruments to assess teacher candidates during their online field experience. This would require pilot programs (with exceptions to where regulations would first need to be approved), which would include finding partner schools with whom to collaborate. If successful, these pilot programs could facilitate changes to programs. In addition, faculties of education need to address online teaching in both the hiring process as well as the tenure and promotion process (through professional learning requirements, for example), making sure that new faculty are or can become comfortable and successful teaching online. Last, colleges of education need to initiate conversations with policymakers, provincial governments, and teacher unions to ensure that the needs of all stakeholders are met.

It is understandable that every innovation takes time to be adopted (Hall & Hord, 1987). The adoption often starts with administrators' attitudes (Huberman & Miles, 2013), and these are administrators similar to many of those who were responsible for completing the survey in this study. To better prepare future and current teachers, it will be necessary to help current university administrators understand the benefits and challenges that online or virtual field experiences can provide in preparing teachers to work in the classrooms of the future (Kennedy & Archambault, 2012).

As Woo et al. (2023) and others have suggested, the increase in research on this topic during the pandemic needs to be put into practice. Future studies should begin by examining the effects of changes made to teacher preparation programs regarding online field experiences. In addition to replicating studies such as this one (i.e., tracking changes to online field experiences in Canada), studies could include examining how prepared candidates feel about online teaching several years after completing their teacher preparation program. Further, if remote teaching is necessary due to another pandemic or climate disaster, research could look at how teachers adapted this time, as well as whether learning loss was mitigated when compared to the COVID-19 pandemic. The topic of online field experiences is in its fourth decade, and while the throughline from research into practice in education is often slower than desired, this particular topic is inherently fast-paced, necessitating a sense of urgency for institutions and policymakers to make research-based change.

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Implementing a Flipped Learning Approach With TPACK in Grades 6 to 9

Mise en œuvre d'une approche d'apprentissage inversée avec TPACK de la 6e à la 9e année

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Abstract

In this design-based study, a flipped learning approach using audio-visual resources as prelearning activities was examined in grades 6, 7, and 9 with four teachers and 65 students over one school year. The purpose of this study was to explore the implementation of a technology-enhanced pedagogy in science, math, and social studies. The implementation was sequenced to provide students who were also learning the English language with an opportunity to practice engaging with curriculum concepts through viewing prelearning videos with language tailored by the teacher and with embedded questions, prior to in-classroom learning activities. The technological, pedagogical, and content knowledge (TPACK) framework was used to inform the instructional design for the flipped learning activities. Monthly teacher-researcher professional learning sessions were held, and data were gathered from teachers' reflections and a student survey. Results indicated that teachers had more class time to support students with enrichment, remediation, small group work, and active learning. Students reported that the prelearning video activities benefited their learning and complemented in-class learning activities. This study serves to inform teachers and schools considering implementation of flipped learning to support students' understanding of content knowledge and English language learning, and researchers studying designs using flipped learning sequences.

Keywords: design-based research, flipped learning, technology-enhanced learning, TPACK

Résumé

Cette étude basée sur une approche d'apprentissage inversé utilise des ressources audiovisuelles comme activités de préapprentissage. Soixante-cinq élèves des classes de 6e, 7e et 9e années et accompagnées de quatre enseignants ont participé à cette expérience. L'objectif de cette étude était d'explorer l'introduction d'une pédagogie enrichie par la technologie dans les domaines des sciences, des mathématiques et des études sociales. La mise en œuvre a été séquencée afin d'offrir aux étudiants qui apprenaient l'anglais l'occasion d'interagir en suivant les concepts du programme scolaire en visionnant des vidéos dont le langage avait été adapté par l'enseignant et qui contenaient des questions intégrées. Il est important de noter que cela se faisait avant les activités d'apprentissage en classe. Le cadre de connaissance technologique, pédagogique et de contenu (TPACK) a été utilisé pour informer la conception pédagogique des activités d'apprentissage inversé. Des sessions mensuelles de formation professionnelle pour les enseignants-chercheurs ont été organisées, et des données ont été recueillies à partir des réflexions des enseignants et d'une enquête auprès des élèves. Les résultats ont indiqué que les enseignants disposaient plus de temps en classe pour soutenir les élèves en matière d'enrichissement, la remédiation, le travail en petits groupes et d'apprentissage actif. Les élèves ont rapporté que les activités de vidéos de préapprentissage leur avaient été bénéfiques et avaient complété les activités d'apprentissage en classe. Cette étude sert à informer les enseignants et les écoles qui envisagent de mettre en œuvre l'apprentissage inversé pour aider les élèves à comprendre la connaissance du contenu et l'apprentissage de l'anglais, ainsi que les chercheurs qui étudient les modèles utilisant des séquences d'apprentissage inversé.

Mots-clés : apprentissage inversé, apprentissage amélioré par la technologie, recherche basée sur la conception, TPACK

Introduction

Flipped learning is a pedagogical approach that integrates technology through prelearning designed to be completed independently by students outside of class time, leveraging video and other mediums, followed by learning activities completed during class time (Brown et al., 2022; Mazur et al., 2015). In this study, flipped learning is defined as (a) out-of-class learning activities that use audio-visual materials to prepare students for classwork, followed by (b) in-class activities that involve group work and the real-world application of concepts students learned from the audio-visual materials (Lo & Hew, 2017). This definition is consistent with that provided by the Flipped Learning Network (2014), a nonprofit online community for educators interested in flipped learning practices.

Flipped learning has been documented as a beneficial approach to support student learning related to self-directedness, autonomy, and agency because of how empowered students are to learn prior to classroom activities (Chao et al., 2015; O'Flaherty & Phillips, 2015). Flipped learning has been associated with increases in English language learning as this method builds students' confidence in learning and can contribute to student achievement (Chuang et al., 2018; Graziano & Hall, 2017; Webb & Doman, 2016). Flipped learning sequences using video to introduce prelearning concepts have been shown to increase motivation, engagement, confidence, and academic achievement for students who are also learning the English language (Graziano & Hall, 2017; Pang, 2022; Webb & Doman, 2016).

Akin to how these unique designs and learning sequences can be achieved, there is increasing demand for meaningful and sustainable technology-enhanced approaches in education. There is much to be learned from examining the prelearning activities that are complementary to in-class activities in a flipped learning approach and the outcomes for students and teachers. This question guided the study: How do teachers and students perceive the implementation of flipped learning with prelearning activities followed by in-class activities?

Literature

Prelearning Activities

Flipped learning has been used across multiple disciplines in kindergarten to Grade 12 (Lee & Choi, 2019), and research has demonstrated that learners benefitted when multimedia was used for prelearning activities (Aidinopoulou & Sampson, 2017; Jong et al., 2019). Mischel (2019) noted that students assigned asynchronous video content for prelearning reported positive feedback, indicating that using videos helped them focus on the important aspects of the topic and that they were more confident of the learning after taking embedded quizzes. Students felt a higher rate of perceived learning readiness when given opportunities to view videos and engage in video lessons before in-class activities (Lee & Choi, 2019; Lo, 2017).

Slemmons et al. (2018) investigated how middle school science students responded to short (< 10 min) versus long (> 10 min) videos, using surveys and quiz results to assess. Students were divided into these two groups and received the same content. At the end of each video, students were assessed on both the content of the video and their attitude towards its length. Students watching the short videos reported a greater degree of engagement, focus, and ability to retain content compared to their peers in the long video group (Slemmons et al., 2018). Designs for prelearning activities in a flipped learning sequence could include assigning short videos for introductory knowledge with surveys or quizzes to help students focus on the topic and develop overall confidence and readiness for the subsequent in-class activities.

Viewing videos as prelearning activities enabled students to understand content, gave them a greater level of autonomy and independence (Muir, 2021; Santikarn & Wichadee, 2018), and enabled them to develop introductory knowledge (Fung, 2020). The implementation of a flipped learning approach provides students with the agency to watch videos, rewatch sections as needed, and focus on areas that need further development (Brown et al., 2022; Sun et al., 2016; Unakorn, 2015). A study by Putri et al. (2019) noted that flipped learning allowed students the opportunity to learn in their own ways and be flexible in managing their time for studying, thus increasing student responsibility for their learning process. Designs for prelearning activities in a flipped learning sequence could include flexible activities to increase autonomy, independence, and agency and prepare students for in-class activities.

In-Class Activities

Teachers need to carefully design the sequence of activities to make the in-class instruction complementary to the prelearning activities (Kinnari-Korpela, 2015; Wiese & Newton, 2013). Using a flipped learning model can help personalize student learning during in-class activities (Muir, 2021; Zupanec et al., 2022). In a study by Winter (2018), average-achieving students in Grade 6 social studies benefited from flipped learning especially when differentiated strategies were used during in-class instruction. In a study comparing traditional and flipped learning approaches in Grade 7, Al-Abdullatif (2020) found that students participating in a flipped classroom approach practiced metacognitive self-regulation learning strategies. Knowing that they would be able to ask questions during class time about their prelearning, the students felt more engaged in classes where flipped learning was used (Bond, 2019).

In a study related to conceptual understanding and competency development, Fisher et al. (2017) asserted that students had more classroom time for critical reflection because the introductory content was provided in advance of the class. Additionally, teachers were able to support a deep understanding of concepts with the in-class activities following the prelearning activities (Fisher et al., 2017). Designs for in-class activities in a flipped learning sequence could include differentiated instruction and opportunities for students to engage in critical reflection and metacognitive learning.

Increased Engagement During In-Class Activities

Putri et al. (2019) reported that the flipped learning method allowed teachers and students to participate in student-centred learning during class time and students engaged with the in-class material more readily than with traditional approaches. In mathematics, for example, researchers argued flipped classroom approaches could improve mathematics achievement (Bhagat et al., 2016; Wei et al., 2020) and provide more opportunities for students to apply their knowledge during in-class activities (Lo, 2017). Additionally, flipped learning has been shown to benefit students in science-based inquiry (Chang & Hwang, 2018), engagement in junior high mathematics (Brown et al., 2022), and active learning in social studies (Mazur et al., 2015).

Flipped learning can also increase interaction between teachers and students during class time (Jong et al., 2019). Students can foster strong connections with each other when in-class activities involve groups with the support of the students' instructor (Brown et al., 2022; Singay, 2020). These academic connections enable students to actively participate in class because of the highly engaging learning environment created with a flipped learning approach (Singay, 2020). Students have opportunities to distill their understanding of concepts being explored by engaging in group discussions with peers and asking them questions (Alfares, 2017; Taqi & Al-Nouh, 2014). Students' responses in Taqi and Al-Nouh's (2014) study reflected this sentiment, as they expressed enjoyment in working in groups with classmates, and many felt their communication skills improved as a result of group work and interactions with peers. Designs for in-class activities in a flipped learning sequence could include student-centred approaches, active learning, interactions between teachers and students, interactions among peers, group work, and opportunities for communicating with peers.

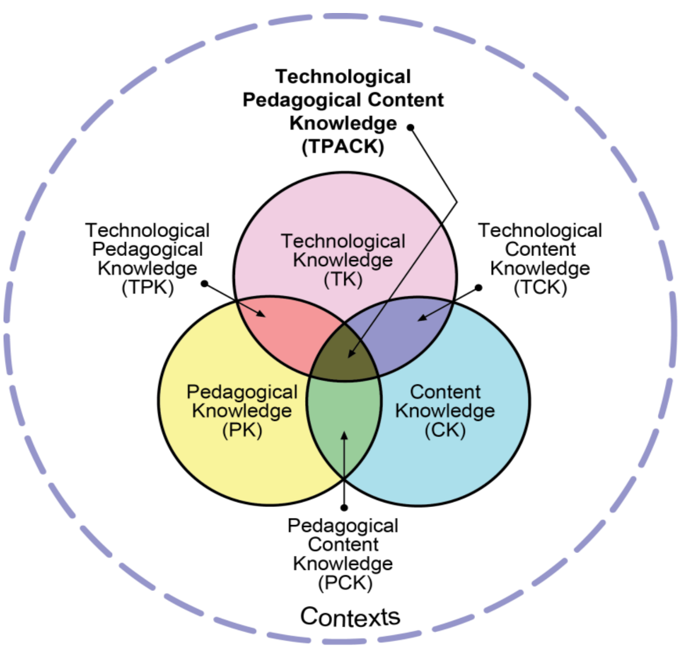
Flipped learning can provide rich opportunities for student engagement with in-class activities that are intentionally designed to follow prelearning activities, such as viewing a content video and completing an embedded practice quiz. Teachers can tailor in-class activities based on the students' engagement with prelearning activities. Overall, once flipped learning sequences are integrated as part of the class proceedings, in-class activities can be responsive to students' learning needs.

Theoretical Framework

The technological pedagogical content knowledge theoretical (TPACK) framework denotes the importance of considering multiple dimensions when designing and integrating technology-enhanced practices in a classroom in order to coalesce areas such as content, pedagogy, and technology (Voogt & McKenney, 2017). The TPACK framework (Mishra & Koehler, 2006) was used in the conceptualization of this design-based research study and informed discussions with the teachers and their reflections when using a flipped learning approach (Voogt & McKenney, 2017). The framework was used to coach and support teachers as they designed and implemented flipped learning with the intent to create more sustainable and engaging practices (Wu et al., 2022). Teachers integrated technology into their teaching by designing flipped learning sequences of prelearning activities and in-class activities with attention to the content knowledge, pedagogical knowledge, and technological knowledge needed for each sequence. The framework supported the preliminary preparation for the teachers in implementing flipped learning as well as the design adjustments made throughout the design-based research study. Using TPACK as a theoretical backdrop helped provide a consistent design frame for dialogue using the three domains and the four subdomains: pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge, as shown in Figure 1.

Figure 1

TPACK Framework



Note. TPACK = technological pedagogical content knowledge. From *Using the TPACK Image*, by M. J. Koehler, 2011 (http://matt-koehler.com/tpack2/using-the-tpack-image/). Copyright 2011 by tpack.org. Reproduced with permission.

Methodology

In this design-based research study (McKenney & Reeves, 2019), a flipped learning intervention was implemented in math, science, and social studies classes in a junior high/middle school that supports students who are learning the English language. This study included professional learning to support teachers in designing and implementing flipped learning sequences and built on an earlier study and design cycles that occurred during the pandemic in two mathematics classes (Brown et al., 2022). During the present study, classes were held at the school site, but teachers, students, and their families were familiar with using technology to access assignments outside class time. Teachers used other pedagogical practices during this timeframe as well, selecting suitable lessons for implementing a flipped learning sequence of prelearning activities followed by in-class activities.

Participants

Classes from grades 6 to 9 were involved in the study with a total of four teachers and 65 students ranging from the age of 10 to 16 years. The teachers who were all new to integrating a flipped learning approach volunteered to participate in a series of monthly literature-based reflective conversations and professional learning sessions to design prelearning activities using a flipped learning approach, that is, using a video and embedded quiz online application (Edpuzzle, https://edpuzzle.com), which linked to Google Classroom (https://classroom.google.com) and the gradebook. In these sessions, teachers worked alongside members of the research team to design flipped learning sequences of in-class activities that would follow the prelearning video and quiz activities.

Data Collection

As part of the design-based research process, teacher participants worked with the research team to determine suitable data collection methods. Data sources included the four teachers' reflections and student surveys. Teachers were invited to respond to questions such as, "How did your prelearning design inform the in-class activities?" and "What could be modified to strengthen the design?", aiding them to articulate strengths and challenges, insights about implementation, and their experiences with their classes. Students were surveyed to ascertain their perceptions of the flipped learning approach, responding to statements using a Likert scale (*4= strongly agree to 1= strongly disagree*). Students also had the opportunity to add comments or provide reasoning for their selections. The surveys were sent to 116 students, with 65 total respondents (56% response rate) across grades 6, 7, and 9 with parent consent and student assent. Teachers used the video/quiz tool in Google Classroom for students as part of the flipped learning approach. In this article, we report on the results of the surveys and the themes that arose from the teachers' reflections.

Data Analysis

For the qualitative data, content analysis was used for the teacher reflections. We created descriptive codes that represented the main ideas in the reflections and then grouped the responses into categories related to similar themes. Two members of the research team completed the initial coding of the reflections, followed by a discussion with all members of the research team. The team members conducted an additional round of coding and compared their codes to establish agreement and intercoder reliability (Miles et al., 2014). A similar process was used for coding the text-based responses from the student survey. We then used the data visualization application Tableau (https://www.tableau.com) to tabulate the data into the frequency of phrase and word responses at a scale of 10:1. This scale helped us cross-reference our own coding and content analysis with that yielded by Tableau and served as a check based on the frequency of responses. For the quantitative survey data, we used descriptive statistical analysis including the frequency and percentage to determine the levels of agreement/disagreement related to the survey questions and the relationship to the research question.

Findings

Student Responses

In the survey, 90.8% of students agreed or strongly agreed that they were satisfied with the flipped learning approach. Survey respondents agreed the videos used in the prelearning activities supported their learning. Additionally, they indicated that the videos were easy to understand, and having the opportunity to view the videos or sections in the videos multiple times was regarded as helpful by most students. Moreover, the prelearning videos and activities helped students come to class prepared with questions. In addition, 92.3% of students agreed or strongly agreed that the learning activities designed for the in-class portion of the flipped learning sequence helped their learning. Just over 15% of student respondents shared that the videos did not help them prepare for asking questions during class time. Table 1 shows the results of the student survey.

Table 1

*Student Survey Responses About Prelearning and In-Class Learning Activities (*N *= 65)*

Survey statement	Student response			
	Strongly agree *n* (%)	Agree *n* (%)	Disagree *n* (%)	Strongly disagree *n* (%)
I am satisfied with the flipped approach used in class.	17 (26.2)	42 (64.6)	5 (7.7)	1 (1.5)
The learning activities in the videos help me understand what I need to learn in class.	20 (30.8)	41 (63.1)	3 (4.6)	1 (1.5)

Survey statement	Student response			
	Strongly agree *n* (%)	Agree *n* (%)	Disagree *n* (%)	Strongly disagree *n* (%)
The learning material in the videos is easy to understand.	20 (30.8)	38 (58.5)	7 (10.8)	0 (0.0)
It is helpful for my learning to view parts of the video more than one time.	29 (44.6)	32 (49.2)	3 (4.6)	1 (1.5)
The videos help me to come to most classes prepared with questions in mind that I seek answers to.	17 (26.2)	38 (58.5)	8 (12.3)	2 (3.1)
The learning activities in the classroom help me understand what I need to learn in class.	22 (33.8)	38 (58.5)	4 (6.2)	1 (1.5)

Most survey respondents (66.2%) indicated that they were very willing or somewhat willing to ask their classmates questions in class, and 76.9% reported a willingness to ask their teacher questions about concepts in class. Most (75.4%) also reported a willingness to offer their opinions and felt comfortable communicating during whole-class discussions. Lastly, 86.1% of respondents indicated a willingness to offer their opinions and said they felt comfortable communicating in a small group discussion. Of note, 9.2% of respondents reported they were very unwilling to ask questions to the teacher or offer their opinions in class discussions. Table 2 shows the student survey results for questions about communications during in-class activities.

Table 2

*Student Survey Responses About Communication During In-Class Activities (*N *= 65)*

Survey statement	Student response			
	Strongly agree *n* (%)	Agree *n* (%)	Disagree *n* (%)	Strongly disagree *n* (%)
I ask my classmates questions in class.	15 (23.1)	28 (43.1)	18 (27.7)	4 (6.2)
I ask the teacher questions about concepts in class.	14 (21.5)	36 (55.4)	9 (13.9)	6 (9.2)
I offer my opinions and feel comfortable communicating in whole-class discussions in class.	12 (18.5)	37 (56.9)	10 (15.4)	6 (9.2)
I offer my opinions and feel comfortable communicating in small group discussions in class.	27 (41.5)	29 (44.6)	6 (9.2)	3 (4.6)

Students provided text responses to open-ended questions, noting the benefits of flipped learning and offering suggestions for improvement. The sample quotations in Table 3 illustrate student perspectives about the benefits of the flipped learning approach, which may not have been garnered from the survey alone. Themes emerged, such as the positivity with which students embraced the flipped learning approach, and this was reflected in statements highlighting how the prelearning and in-class sequences supported their learning. Some respondents also offered suggestions for improving future implementation.

Table 3

Student Survey Quotations: Benefits and Suggestions for Improvement

Student	Quotation
1	"The flip is really useful to me I understand much more when I am watching the videos."
2	"I think this was an easy way to know what experiments we are gonna do in class it helps me to understand what we will be learning."
3	"I am able to focus more when I watch videos and when I can rewatch them."
4	"I find it very helpful and I can always understand any upcoming questions."
5	"Flipped learning could be improved by making the videos shorter and also easy to understand."
6	"I would like to learn about different situations which are still happening around the world like about Palestine, Syria, Yemen and other countries which are suffering."

When using the flipped learning approach, teachers continually reflected and engaged in professional learning with the researchers to discuss ways to design their instruction with Edpuzzle and what information would support the learning sequence. Teachers also maintained a diary of reflections regarding the progress of implementation, adjustments made, and the affordances and constraints of flipped learning, and these reflections were analyzed for common themes. The following themes emerged from the analysis of the teachers' reflections on their experiences with the flipped learning approach: student-centredness, confidence, personalized support, active learning, agency, equity, and literacy.

Teacher Reflections

Student-Centredness

In their reflections, teachers noted a priority for student-centred approaches in developing technological, pedagogical, and content knowledge through designing flipped learning sequences. Student-centredness was viewed as how teachers could use instructional methods, such as the questions in the video and formative assessment segments, to create active engagement for students rather than spending time on factual recall. For example, a teacher reflected on how the prelearning video/quiz data highlighted areas of struggle for students in relation to ionic compounds. The teacher was then able to design the in-class learning activities with opportunities for students to develop a deeper understanding of ionic compounds. The teacher estimated that having access to the prelearning formative assessment data from the video/quiz activities saved time equivalent to at least one class period. The prelearning activities helped students prepare for in-class learning and also supported the teacher in gathering formative video/quiz results for how each student was engaging in the prelearning activities.

Additionally, in the prelearning for each topic area, the teachers thought about and enacted ways in which students could learn content knowledge including key vocabulary and apply them to the in-class activities, which included labs in science or using manipulatives in math-based learning sequences. The self-guided sections were scaffolded so students could understand how the prelearning connected to the learning sequence for the in-class activities to enhance students' understanding of what was being learned, how this learning related to real world contexts, and how they could engage with the material more meaningfully. One teacher noted the option to add customized quiz questions to the videos required technological knowledge so the prelearning activities could also be responsive and align with the learning sequence and in-class activities. For example, trading cards with key vocabulary (i.e., disciplinary literacy) were highlighted in the prelearning videos and then used in class to support understanding as it related to the periodic table and the chemical elements and for math concepts. Teachers' reflections across the disciplines highlighted how this approach required technological, pedagogical, and content knowledge to support a student-centred design.

Confidence

Teachers initially expressed reluctance to use the video/quiz tool for several reasons. First, many teachers had never experienced technology-enhanced teaching practices and discussed how the teaching methods they regularly used did not require technological knowledge. Second, teachers expressed an added layer of pressure to communicate information about the use of the video/quiz tool with parents and keep track of students' permission slips. Finally, teachers thought flipped learning would take more class time to teach students how to use the video/quiz tool effectively, such as demonstrating how to rewatch a video and redo assigned activities. However, as teachers became accustomed to the video/quiz tool, they noted its straightforwardness. Teachers also felt more confident with the flipped learning approach as they found relevant videos which supported the learning sequences and aligned with the content in the program of studies. One teacher noted that, despite feeling "obviously hesitant" to change their methods after six years of teaching, employing the flipped learning approach became simple and ultimately resulted in positive outcomes for students.

While it was still prevalent, the learning curve was less dramatic for students. Teachers quickly observed students' increased confidence when the flipped method was employed. This confidence manifested through students asking deeper questions, communicating their ideas more often with their teacher and classmates, and raising their hands to contribute during in-class discussions. This was especially notable in students who were previously less engaged during classes. For example, one teacher noted that three quiet students who were not particularly strong learners started whispering their answers in class, and their answers became more accurate, possibly because of rewatching videos and taking part in the prelearning activities.

Personalized Support

From a pedagogical perspective, teachers found that implementing a flipped learning approach enabled them to provide more support and accommodations for students, which included grouping students by ability. Teachers also described being able to engage with and help more students in a responsive capacity and attend to individual questions, thus personalizing students' learning. For example, one teacher said they used the embedded formative feedback from students' responses to video/quiz questions to purposefully arrange small groups during the in-class activities. Using the video/quiz features to gather information about students' learning prior to class enabled the teacher to spend more time with targeted groups of students who needed extra support. A similar sentiment was echoed by another teacher who divided students into independent study groups and pulled those who needed extra personalized support based upon the results of their prelearning video/quiz activities. Utilizing the prelearning methods at the beginning of the learning sequence provided more responsive and effective opportunities for personalization in a timely manner from the outset of the learning. By grouping students by ability, teachers reflected that they were able to differentiate and personalize learning during the in-class activities. Teachers reported several ways in which the flipped learning model gave them more time to support student learning in class, which meant that students who were struggling could be more aptly supported.

Active Learning

The prelearning formative assessments embedded in the videos provided rich data and targeted evidence of where students were at in their learning or where they experienced gaps in understanding. Teachers realized that by going over concepts in class after students had watched the video, they did not need to spend as much time providing conceptual information and that students found it easier to understand content. The video/quiz results provided teachers with insights on how to continually adapt and design responsive in-class learning activities.

Teachers speculated that student engagement in the prelearning video/quiz activities created opportunities for students to work with the content more meaningfully during the in-class activities, to expand their understanding of the concepts, themes, vocabulary, and learning processes. As a result, there was more time to design engaging learning activities during in-class time. Teachers described an increase in student engagement during in-class activities and attributed this to increased hands-on time interacting with materials. This was especially apparent during science labs conducted in-class, as students arrived with prelearning activities completed and had more opportunities to work through the final process of their experiments in class. Prior to using the flipped approach, teachers explained that they had to dedicate considerable amounts of lab time to explain the procedures and provide instructions, which left students with limited time to conduct the lab and synthesize the results of their experiments. In addition, teachers perceived that students were more capable of seeing how concepts and topics connected with the added time for experimentation.

Student Agency

Throughout the flipped learning intervention, teachers observed an increase in students' agency and ownership of their learning. *Agency* refers to the students taking more initiative and allowing their interests to guide their learning, and *ownership* refers to the appreciation, sense of autonomy and choice, and increased responsibility over one's learning. In their reflections, teachers noted that these changes in agency and ownership were not immediate and only became evident once students started to become accustomed to the flipped learning sequence. Students were able to view and engage with materials on their own time and learned the value of rewatching sections of the videos or slowing the video down. When looking at the data analytics on the video/quiz tool, teachers also noted that many students would reattempt questions to best grasp concepts, even though the assessments were only formative. Teachers reported that students seemed keen to take part in conversations about content in class and that discussions were richer when using the flipped learning approach. Where teachers would have simply told students answers to questions in, for example, social studies content areas, students seemed eager to research and would seek out information themselves.

Teachers noted that students participated more readily in classroom discussions and that students were excited to share what they learned more than when using traditional approaches. In some content areas, students were able to move their thinking, curiosity, and questioning to reflect higher levels of cognition, which one teacher shared was exemplified in the types of questions asked after the flipped learning approach had taken root. Across math and science, teachers reflected on the in-class activity design and reflected that most students were more apt to explore further from the initial prelearning provided with video/quiz activities. For example, in science, preparation for lab activities and initial simulations were provided for students before they did the actual lab in class. Many students shared that they explored more content by examining online educational resources so they could inquire about each of the labs prior to their in-class lab time.

Equitable Access

When the flipped approach was first introduced, teachers reported having concerns about students' accessibility to the tools needed to complete prelearning video/quiz activities. Given that not all students had access to technology at home, this was perceived as a constraint to adopting the flipped approach and ultimately resulted in issues concerning equity. Considerations pertaining to equitable access are imperative for all student populations, as there may be socioeconomic constraints and familial conceptions about in-class work versus homework. Teachers mitigated this limitation by providing access to technology before school started in the morning, during the lunch hour, and after school. While these strategies made the prelearning activities accessible, two teachers expressed that this solution unfortunately resulted in a disruption of the design of the learning sequences given that students were completing the video/quiz activities at varying stages and not necessarily in advance of the in-class activities. In the context of a flipped classroom, teachers recognized it was necessary to incorporate strategies that helped mitigate the issue of access to devices at home, Internet access, and making time for engaging in prelearning activities at school.

English Literacy

In their reflections, many teachers highlighted a main challenge for several students was their literacy, specifically their writing and reading skills in English. Teachers reported that at times, the wording used in the video/quiz was slightly too hard for their students to understand, but that they were able to mitigate this by either choosing specific questions or by rewording questions to include level-appropriate language. Teachers also observed that encouraging students to turn on closed captions when watching videos was beneficial for student comprehension. Another practice used by teachers to support students' literacy was to create videos which better matched in-class content or use a teacher voiceover to emphasize key terms. Overall, teachers reported that the flipped learning approach and designing learning sequences with prelearning activities with customization of the video/quiz content followed by in-class activities supported students' literacy skills and supported the development of discipline-based vocabulary and concepts.

Discussion

Drawing on one of the recommendations from an earlier flipped learning study with two mathematics classes (Brown et al., 2022), we used the TPACK framework as a design frame to help coalesce content, technology, and pedagogy during the professional learning sessions and conversations with teachers prior to and while using the flipped learning approach. The overall results from the teachers' reflections and student survey indicated both groups were satisfied with implementation of flipped learning. In this section, we discuss our interpretations of the results in response to the guiding question: How do teachers and students perceive the implementation of flipped learning with prelearning activities followed by in-class activities?

The results demonstrate the value of using a theoretical frame, such as TPACK, to design and harness flipped learning sequences with prelearning and in-class activities so that students are confident to ask questions and engage with peers during in-class activities and teachers use responsive teaching and adjust in-class activities to support and personalize students' learning. Using the TPACK framework possibly helped teachers to both work through the initial learning curve as they designed learning activities during the professional learning sessions and become more confident in designing and implementing sequences of complementary prelearning and in-class activities. After implementing flipped learning over one school year, teachers reported that they were more confident in using this approach and more apt to design prelearning activities using the video/quiz tool for conceptual instruction and in-class, student-centred, active learning activities, aligning with suggestions from the literature (Chang & Hwang, 2018; Putri et al., 2019). Students also took some time to become familiar with the approach and shared that after experiencing flipped learning, they were more comfortable communicating in smaller groups and had increased opportunities to collaborate with classmates, which further aligns with the literature (Brown et al., 2022; Singay, 2020).

Teachers perceived an increase in the amount of time that could be dedicated to in-class activities. Time was an important construct to consider as part of our interpretations, which was especially apparent when teachers shared that the use of flipped learning afforded them significant time per lesson where they would have been teaching content if they had not implemented the flipped approach. Initially, teachers were hesitant to implement flipped learning as they thought it would require an increased time commitment. However, after implementation, the teachers' reflections indicated the opposite—that using a flipped learning approach provided more in-class time. This additional time was then used either to work with students who were struggling with the content or to be more visible for the whole class as they engaged in hands-on learning activities such as science labs, small group centres, or building enrichment for students who had mastered the outcomes within the lessons. Thus, the increased classroom time that resulted from using a flipped learning approach can provide students with more time to participate in learning activities in the classroom (Putri et al., 2019).

Across the classes using flipped learning, all four teachers in this study included reflections about the positive impact of using the TPACK design frame. They reported having more time to further personalize learning and provide targeted support for students they may not have been able to engage with previously and for creating greater visibility in the learning process (e.g., student centredness, confidence, personalized support, active learning, student agency, equitable access, and English literacy). As affirmed by Jong et al. (2019), the role of the teacher as facilitator can support more efficient uses of class time and does not rely on teachers to be the bearers of knowledge.

Students perceived an increase in readiness for class, and with this advance preparation, they were able to engage more fully during in-class activities. Technology-enhanced approaches for prelearning activities such as designing flipped learning sequences create a unique learning experience for students that can increase learning readiness (Lee & Choi, 2019; Lo, 2017). In the student survey, respondents expressed that the flipped learning approach supported their learning and helped them prepare for in-class learning and become more active in their own learning across multiple classes and disciplines. Across much of the literature, group work and small group discussions with peers has been shown to be highly beneficial for students to distill their understanding (Alfares, 2017; Taqi & Al-Nouh, 2014). Students also reported they were able to assert their own agency (Brown et al., 2022; Sun et al., 2016; Unakorn, 2015) through rewatching videos and repeating quizzes, followed by engagement during in-class activities by asking questions in class (Bond, 2019).

We recognize that student engagement during in-class activities is not simply a result of implementing a flipped learning approach and could be impacted by many factors including teacher support, the quality of instruction, meaningful connections with peers, and the structure and management of the classroom setting (Pang, 2022), and more. Over 15% of survey respondents indicated that the videos did not always help them prepare for engaging in class by asking questions, and 9.2% of respondents reported they were very unwilling to ask questions or offer their opinions in class discussions, so it is important to also recognize that some students did not perceive flipped learning to result in engagement during class time. More research is needed to identify reasons why a small group of students in this study were unwilling to engage in class discussions and to help address this issue in future.

Although this study has limitations, such as the timeframe (occurring over only one school year) and the small number of teacher and student participants, the findings can be useful for teachers considering the design and implementation of flipped learning sequences. We should also note that during this study, participants were uncertain if classes would be required to move to emergency remote teaching with little notice. Similar to a study with two mathematics classes, we found the flipped learning model can be used during emergency remote teaching (Brown et al., 2022), and this may have been one of the reasons that teachers were willing to participate in the professional learning sessions and the study. In a systematic literature review building on previous empirical studies in mathematics education, Cevikbas and Kaiser (2022) also reported that flipped classroom pedagogy is a promising practice during events such as the pandemic. Science, math, and social studies teachers in our study used a flipped learning approach and described their context as a dynamic and shifting learning environment requiring teachers and students to be ready and agile for unexpected changes in the context.

Conclusion

The insights from this design-based study help illustrate the perceptions of teachers and students involved in an implementation of a flipped learning approach using audio-visual resources as prelearning activities over the course of one school year in grades 6, 7, and 9. The study aimed to explore the perceptions of teachers and students when using a flipped approach to learning using complementary prelearning and in-class activities, specifically in the subjects of science, math, and social studies. The instructional design for the flipped learning activities was informed by the principles of the TPACK framework. The implementation of this approach provided students with an opportunity to practice disciplinary concepts and the English language through tailored videos and embedded questions prior to in-classroom learning activities.

The data collected from teachers' reflections and a student survey revealed several positive outcomes. For example, teachers reported having more class time to support students with enrichment, remediation, and small group work when using the flipped learning approach and identified seven benefits in their reflections, including student-centredness, confidence, personalized support, active learning, student agency, equitable access, and English literacy. Most students expressed that the prelearning video activities enhanced their learning readiness and engagement with the in-class activities. However, there were some students who did not benefit from the prelearning activities, and this underscores the importance of examining the many factors that can impact student engagement when implementing flipped learning. A longitudinal study could provide more insights into student engagement. Overall, this study suggests that implementing a flipped learning approach holds promise in supporting students' understanding of disciplinary concepts and can support students who are also learning the English language. Its findings serve as valuable insight for teachers and schools considering the adoption of this pedagogical approach and can provide a foundation for future implementation research.

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Virtual Labs for Postsecondary General Education and Applied Science Courses: Faculty Perceptions

Laboratoires virtuels pour les cours de formation générale postsecondaire et de sciences appliquées : Perceptions des professeurs

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Abstract

General education science courses at a Canadian postsecondary institution implemented *Beyond Labz* virtual science labs. Faculty members teaching vocational science-related courses tested this resource. This qualitative study explores faculty member and learner perceptions of the efficacy of these virtual labs in terms of ease of use, designing hands-on activities, student engagement, and accessibility. Data are collected via a focus group, surveys, meetings, and interview notes. The study found that learners and faculty members may have different perceptions of the importance of virtual labs for the development of various skills. From the data, five themes emerge related to addressing the needs of diverse learners and utilizing multiple affordances of virtual labs. Although science virtual labs are perceived as a useful tool for teaching and learning science, faculty members identify barriers such as the need to develop digital literacy skills and initial training and institutional support when introducing new tools. Recommendations for effective science virtual labs curriculum integration are included.

Keywords: education technology, faculty member professional development, general education, polytechnic institutions, science virtual labs

Résumé

Les cours de sciences en éducation générale dans un établissement postsecondaire canadien ont mis en œuvre les laboratoires scientifiques virtuels Beyond Labz. Les membres du corps enseignant dispensant des cours de sciences à vocation professionnelle ont testé cette ressource. Cette étude qualitative explore les perceptions des membres du corps enseignant et des apprenants sur l'efficacité de ces laboratoires virtuels en termes de facilité d'utilisation, de conception d'activités pratiques, d'engagement des étudiants et d'accessibilité. Les données sont recueillies par l'entremise d'un groupe de discussion, de sondages, de réunions et de notes d'entrevue. L'étude a révélé que les apprenants et les membres du corps enseignant peuvent avoir des perceptions différentes de l'importance des laboratoires virtuels pour le développement de diverses compétences. À partir des données, cinq thèmes émergent concernant la prise en compte des besoins de divers apprenants et l'utilisation des multiples avantages des laboratoires virtuels. Bien que les laboratoires virtuels de sciences soient perçus comme un outil utile pour l'enseignement et l'apprentissage des sciences, les membres du corps enseignant identifient des obstacles tels que la nécessité de développer des compétences en littératie numérique, une formation initiale et un soutien institutionnel lors de l'introduction de nouveaux outils. Des recommandations pour une intégration efficace des laboratoires virtuels de sciences dans le programme d'études sont incluses.

Mots-clés : développement professionnel des membres du corps enseignant, éducation générale, établissements polytechniques, laboratoires scientifiques virtuels, technologie éducative

Introduction

> When Afton-Dawn Ellison messes up a chemistry experiment, the smoke from the explosion and the shattering glass don't distress her. She simply clicks her computer mouse a few times and starts over. (Carnevale, 2003)

The sudden adjustment to online course delivery during the COVID-19 pandemic may have had a negative and lasting impact on students in postsecondary education in Canada (CDLRA, 2020; OCUFA, 2020). The overall quality of educational experience and the ability to adequately teach and support students led to a pilot project at an Ontarian polytechnic institution in Winter 2021. A group of faculty members, with the support of administration and instructional designers, sought to investigate ways to incorporate virtual science labs developed by Beyond Labz (https://www.beyondlabz.com/). Associated benefits and challenges for faculty members teaching general education and vocational science-related courses are identified.

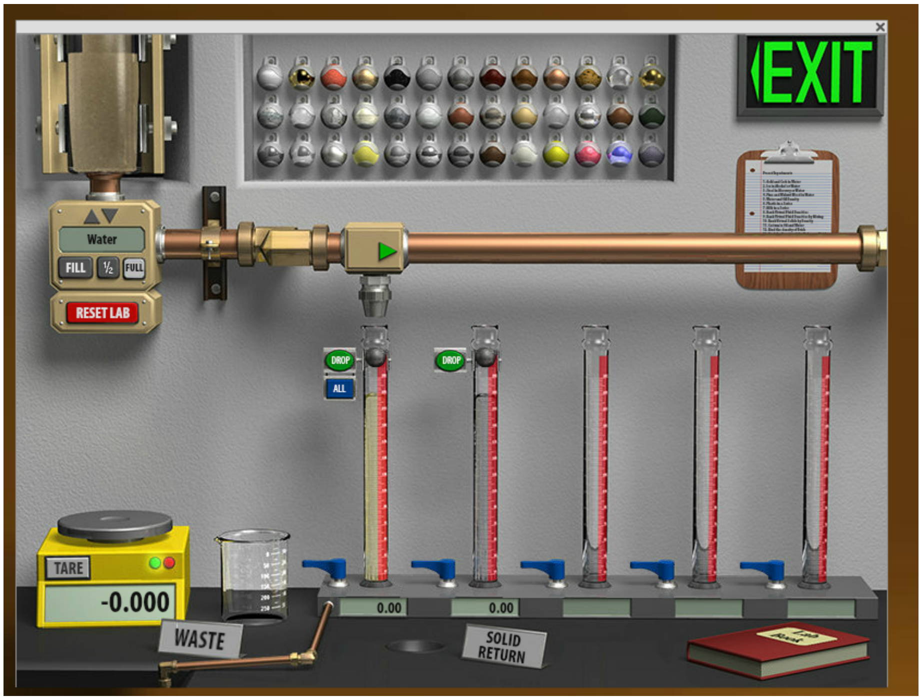
The project consisted of two components:

- Faculty members teaching general education physics and biology courses used virtual labs with students.
- Faculty members from different programs around the college explored Beyond Labz for potential use in their courses.

Beyond Labz is a digital simulation platform built upon actual experimental data and the most advanced models available. This platform offers chemistry, organic chemistry, biology, physics, and physical science labs. Each lab supports hundreds of preloaded experiments and instructors can develop their own activities. For example, Physics Density Lab (Figure 1) supports an experiment in which students are asked to explore the properties of fluids by dropping a Cesium ball into milk (Figure 2). Students press “Drop”, and an unexpected explosion occurs (Figure 3).

Figure 1

Screenshot of Density Lab



Note. Density lab, Beyond Labz. Used with permission.

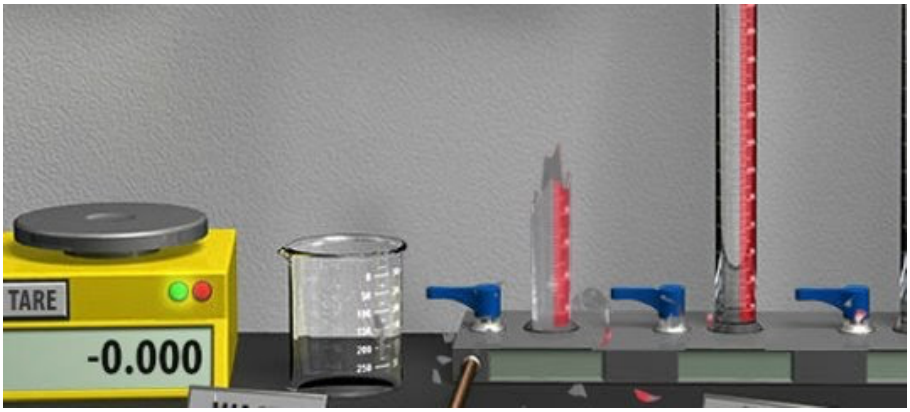
Figure 2

Screenshot of 'Cesium in Milk' Experiment (before)

Note. Density lab, Beyond Labz. Used with permission.

Figure 3

Screenshot of ‘Cesium in Milk’ Experiment (after)



Note. Density lab, Beyond Labz. Used with permission.

By understanding faculty member experiences with using virtual science labs and simulations, faculty member professional development (PD) is supported. The opportunity for students to enjoy and succeed in college science courses is increased, and career-readiness and soft skills development is promoted. Educators must anticipate the range of needs and then plan accordingly to ensure that faculty members and students can experience the full educational potential of science virtual labs.

Literature Review

As online learning has grown and evolved, so has the use of science virtual labs and simulations. Virtual laboratories (VLs) have become an increasingly viable part of teaching and learning (MERLOT, 2019). Virtual laboratories could be useful resources for science education for remote teaching and have been useful during the COVID-19 lockdowns (de las Heras et al., 2021; Ray & Srivastava, 2020). The need for VLs to be integrated in STEM education became even stronger due to subsequent shift towards online/blended learning (European Commission, 2022). There has been increased focus on the integration of technology to support learning in STEM education research (Pavlou & Zacharia, 2024; Zhan et al., 2022).

The importance of laboratory practice in science studies is acknowledged by the educational research community and the pedagogical value of experiments in science teaching is well established. The importance of experiments has been highlighted by many scientists and educators, all of whom praise the overall benefits of experiments in science teaching and online learning (Faour & Ayoubi, 2018; Papaconstantinou et al., 2020; Potkonjak et al., 2016; Tsichouridis et al., 2019; Waldrop, 2013). Virtual laboratories offer affordances that, in some situations, hands-on labs cannot.

Affordances of Virtual Laboratories

Multiple affordances of science virtual lab technology have been identified. Virtual laboratories:

- support students' deep understanding of science concepts and correcting their misconceptions (Bretz et al., 2013; Bruck et al., 2010; Johnstone & Al-Shuaili, 2001)
- provide easy access to resources anytime and anywhere and flexible user interfaces that meet user needs and expectations (Afgan et al., 2015; Makransky et al., 2016; Viegas et al., 2018)
- can support meaningful learning by linking new information with existing information, thus improving students' conceptual understanding of the material (Aljuhani et al., 2018; Hakím et al., 2016; Papaconstantinou et al., 2020)
- reduce equipment needs and offer students more information and the opportunity to work at their own pace while exploring difficult or interesting concepts (Aljuhani et al., 2018; Darrah et al., 2014; Nickerson et al., 2007; Viegas et al., 2018)
- may be most beneficial for students with special needs (Viegas et al., 2018)
- increase non-cognitive outcomes such as motivation and self-efficacy leading to greater educational and life outcomes (Heckman & Kautz, 2012; Heckman et al., 2006; Makransky et al., 2016)
- may be a good way to conduct problem-based learning and develop analytical thinking skills (Klentien & Wannasawade, 2016)
- can be fun for students as curriculum gamification is added (Aljuhani et al., 2018; Carnevale, 2003)
- used as pre-lab exercises, can alleviate real-lab cognitive workload and increase learning outcomes, giving students an effective way to prepare and gain basic knowledge and cognitive skills beforehand, thereby directing their cognitive resources toward the relevant activity in the real lab (Abdulwahed & Nagy, 2009; Makransky et al., 2016)

Research demonstrates that the combination of virtual and real labs best leverages the different affordances of each lab (Abdulwahed & Nagy, 2009; Corter et al., 2011; de Jong et al., 2013; Makransky et al., 2016; Nickerson et al., 2007; Perkins et al., 2010; Tsichouridis et al., 2019; Zacharia, 2007). Faculty members argue that VLs are preferred when costly apparatuses and supplies are needed, or dangerous experiments are involved. Hands-on labs are also needed to familiarize learners with real-life professional tasks and equipment. In general, teachers report that they do not differentiate between the lab formats and support the fact that both labs are essential to achieve a holistic view of reality (Tsichouridis et al., 2019).

Digital Literacy for Educators

Incorporating VLs in distance learning requires students and teachers to have relevant digital literacy skills. Currently, the discourse on implementing digital technologies in higher education settings focuses more on student learning than on faculty teaching (Guri-Rozenblit, 2018). It is acknowledged that digital literacy skills vary among educators and that not all faculty are digital natives. There is a need to rethink the educators' role in planning and applying technologies to enhance and transform student learning, and to develop ongoing PD to ensure faculty competencies to integrate technologies in their professional practice. The following studies explored teacher digital and media literacy:

- Teachers have low levels of digital safety literacy; facilitating the development of digital literacy is one key challenge faced by schools today, and common teacher technology competencies for teacher education is needed (Borthwick & Hansen, 2017; Tomczyk, 2020).
- Teacher competency to create effective learning environments for students is needed (Hassan & Mirza, 2021; UNESCO, 2018). The main reason for not using technology in schools was the lack of teacher digital skill (Anisimova, 2020; Hassan & Mirza, 2021).
- Teachers reported that digital literacy was a very important skill; 94% of participant teachers reported the need for training (Hassan & Mirza, 2021).
- Borthwick and Hansen (2017) identified that there was little research on effective pre-service teacher preparation in technology use.
- Falloon (2020) provides an extensive analysis of existing digital literacy frameworks and presents a conceptual framework introducing an expanded view of teacher digital competence to better prepare future teachers.
- A digital literacy framework within the teacher education sector including "digital literac(ies) for openness" (Gruszczynska et al., 2013, p. 197) and drawing on socio-cultural models of digital practice has been extensively explored (Davies & Merchant, 2014).
- The Information and Communication Technologies Competency Framework for Teachers explains competencies in use that allow teachers to deliver quality education (UNESCO, 2018).

Research on Virtual Labs

A literature search showed that multiple studies explored the use of VLs and their effectiveness and impact on

a) university students (Afgan et al., 2015; Branan et al., 2016; Corter et al., 2011; Darrah et al., 2014; de las Heras et al., 2021; Makransky et al., 2016; Papaconstantinou et al., 2020; Viegas et al., 2018), and
b) secondary school students (Ambusaidi et al., 2018; Ismail et al., 2016; Perkins et al., 2010; Rajendran et al., 2010; Trúchly et al., 2019).

Also, the topic of student support to use VLs was explored. Zacharia et al. (2015) identified potential types of guidance to support student inquiry when using VLs. Surprisingly, only a few studies explored teacher perspectives on the use of science VLs for teaching and learning (Anisimova, 2020; Guri-Rozenblit, 2018; Hassan & Mirza, 2021; Lima et al., 2019; Makhmudov et al., 2020; Tsichouridis et al., 2019). Technology-enabled teaching and learning, when implemented effectively, has a positive impact on teaching and learning but a negative impact when not implemented appropriately (Bull & Keengwe, 2019; Ma & Nickerson, 2006).

This study helps reduce the research gap by exploring college faculty member perceptions of the efficacy of virtual science labs. These results are relevant to other Canadian polytechnic institutions and can support curriculum integration of science VLs. The objectives of the study include:

- Exploring faculty member perceptions of the efficacy of science virtual labs for general education and applied courses.
- Identifying benefits and challenges in integrating this technology into science college courses.

The Study

Participants

The call for participation was posted on the Microsoft Teams Institutional Community of Practice space in December 2020. Twenty faculty members from different areas of the college attended the briefing session. Ten faculty members remained on the project representing the following areas of the college:

- Liberal Arts and Sciences
- Engineering
- Nursing
- Dental
- Pre-Health
- Instructional Design

Seven faculty members had access to Beyond Labz to explore VLs for potential use in science-related vocational courses. Two faculty members used Physics and Physical Science labs and one used Biology labs for teaching general education courses in Winter 2021. Virtual labs served as live demonstrations during synchronous sessions, as a substitution for hands-on synchronous or asynchronous activities (providing the first-ever labs to this biology course), and as assessment activities (virtual labs were worth 10% of the total course mark). Faculty and an instructional designer met bi-weekly to share their observations, concerns, and successes. Although each faculty member designed their own instructional activities, the ground rules were collaboratively agreed upon (Figure 4) and provided common ground for designing student support and course learning activities and assessment (Figure 5).

Figure 4

Sample Agreed Upon Rules for Virtual Laboratory Integration

- Post information on Blackboard about Beyond labs for students to get familiar with the resource.
- Provide instructions on how to get access to the resource and download labs.
- By week 3 assess the number of students without access to the labs and inform the Project Lead.
- Use virtual labs as instructor's demonstration during live sessions at least one time before the introductory activity.

Note. Author's own image.

Figure 5

Sample Activity Design

Cesium in Oil and Water

Instructions:
Go to "Density" lab. Click on the clipboard in the right top corner of the screen. Open preset list. Then choose "Cesium in Oil and Water" and click on it. All the equipment will be set up.

Purpose:
To explore what happens when you drop cesium metal in oil and water.

Materials:
Two graduated cylinders; olive oil, water, two cesium balls; timer; lab book.

Procedures:
1. Drop the ball in the 1st cylinder. Write down the time it takes to reach the bottom.
2. Drop the ball in the 2nd cylinder. Write down what happens
3. Fill out the table below.
4. Click "Exit" to leave the lab

Data Recording:
Fill out the missing information

Table 2

Cylinder (from left to right)	Liquid type	Liquid volume, ml	Time, seconds
1			
2			

Analysis:

Conclusion:

Note. Author's own image.

Research Design

The present study employed a qualitative research paradigm (Lincoln & Guba, 1985) and a single-case study research design to investigate faculty member perspectives on using science VLs. Selecting a qualitative case study research design allowed research to occur within a real-life context and provided means to deeply understand participants' lived experiences (Merriam, 1998; Yin, 2003), and understand the multiple perspectives that define the phenomena under study (Denzin & Lincoln, 2011).

This study used method triangulation to facilitate the cross-verification of data and represent the participants. Methods of data collection involved a) faculty member pre-survey (Appendix A) and post-survey (Appendix B); b) student post-survey (Appendix C); and c) faculty focus group transcripts, detailed research observation notes; transcripts from four semi-structured interviews with faculty members and peer debriefing. Data collection tools were approved by the Institutional Research Ethics Board. The data was organized around frequently noted topics.

The trustworthiness criteria identified by Lincoln and Guba (1985, 1986) were addressed in the following ways: to improve confirmability, two researchers separately coded the qualitative data, compared codes, and identified themes in data collaboratively; peer-debriefing and an opportunity for participants to review and comment on the accuracy of interpretations and conclusions helped improve researcher reliability and credibility; and the fact that participants represented different areas of the college helped improve transferability and relevance to other Canadian polytechnic institutions.

Findings and Discussion

Pre-survey

A student pre-survey was not conducted. Table 1 shows the pre-survey characteristics of participating faculty (response rate = 100%). Faculty goals for the study included learning about new technology tools for student engagement and active learning, forming a community of practice, and best learning practices. For example, one faculty member responded, "*Find interactive ways to engage learners in class materials; get additional insight into creating immersive online learning activities*", while another wrote, "*To find labs/simulations that will support the theoretical part of the course.*"

Table 1

Characteristics of Faculty Members (n=10)

Characteristic	# of Responses	Percentage
Teaching experience of 6-15 years	6	60%
Teaching experience of 16+ years	4	40%
Have no network of teaching colleagues to share and reflect on best practices for the use of VLs	6	60 %
Have an informal community of practice that meets from time to time	4	40%
Not familiar with VLs	7	70%

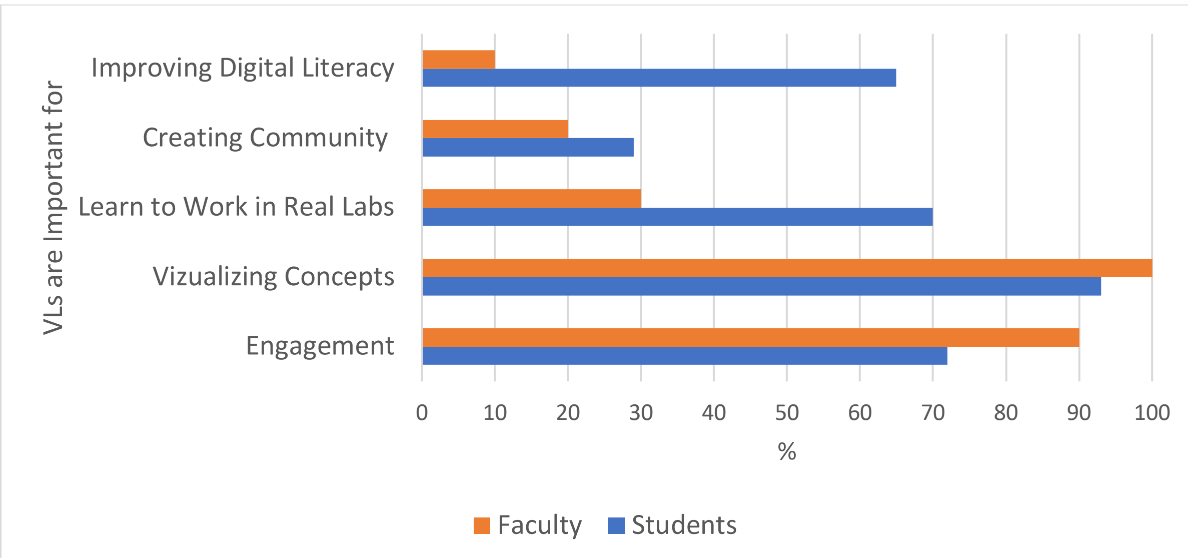
Post-survey

Post-survey response rates for faculty were 100% but only 22% for students. The low student response rate may be due to the length of the survey or because it was a lower priority compared to their vocational courses. Both faculty members and students provided their perspectives on the importance of VLs (Figure 6). The results demonstrated eye-opening perception differences about the value of VLs.

Faculty members perceived VLs as a tool to develop digital literacy and demonstrate how to work in a real lab; much less important than how students perceived VLs. On the other hand, faculty members may overestimate the tool's engagement feature: adding technology to the course does not automatically make it engaging for students. This emphasized the need to relate the choice and use of media to other factors such as learner needs and values, pedagogical context, and learning outcomes in addition to the design of multimedia materials (Bates, 2019).

Figure 6

Comparison of Faculty and Student Perceptions of Affordances of Virtual Labs



Three faculty members, who taught with Beyond Labz, had 135 students in five classes: four sections in a Physics course and one section in a Biology course. Due to the nature of general education courses, students were from a variety of programs and between the first to sixth semesters. Some students decided to forfeit 10% of their course mark to not complete the VLs due to the additional effort required to learn how VLs work.

Analysis of Focus Group Discussions and Meeting Notes

Faculty members suggested that by integrating Beyond Labz into science courses both levels of engagement and opportunity for active learning increased in the classroom. General feedback from faculty members showed that VLs were a good way to engage students with science exploration. One participant stated:

> *I loved the fact that explosions and broken glassware can happen without warning - just like in a real lab. Really made you think about why. Most virtual lab software doesn't allow for this type of "random" effects.*

However, faculty members experienced a learning curve when integrating VLs into their courses. When reflecting upon their experiences, faculty members from applied programs such as dental or nursing reported that due to the nature of their courses and curriculum load, they do not have time ("*unfortunately*") to introduce new tools and teach students how to use them.

Five themes emerged from the data: a) it is important to address diverse student population needs and to consider access and accessibility issues, b) VLs have the potential to enhance learning, c) successful virtual lab integration requires instructional support for students and faculty members alike, d) implementing VLs presents some barriers, and e) it is essential for faculty members to develop digital literacy skills.

These findings agree with findings in other contexts (e.g., Rueda-Gómez et al., 2023). Such similarity, in factors for successful integration of VLs or another online platform in the classroom, suggests that emphasis be placed on adjusting implementation plans and support to the targeted groups. Hence, the types of institutions (e.g., university or polytechnic), the types of students (e.g., taking a diploma or degree program), and course subject matter may be less important.

It is Important to Address Diverse Student Population Needs and to Consider Access and Accessibility Issues

According to the American Council on Education (2019), higher education institutions experience unprecedented diversity of learners. The faculty members mentioned different levels of previous knowledge and different interest levels in learning. One participant highlighted the importance of considering different student attitudes toward learning: VLs as "*assessment will do, optional may ignore*". One faculty member was concerned with "…*different age groups and not curious about digital learning*".

Beyond Labz was designed for university science students majoring in special disciplines who usually start working with VLs and have more background knowledge and lab skills. These students are often more inclined to explore concepts for their own sake. However, based on the data, faculty members recognized that some college students, especially those with previous postsecondary education experience, tended to enjoy the process of exploring the platform while others needed to be scaffolded through the steps. One faculty member shared:

> *For sure, you know as a professor there is a whole range of students. There are for sure students who reach out and they're like, "I got stuck in step one. Help me figure out how to do step two." They want to get it exactly right. So there are for sure that type of students. But I think the software enables the more explorative curious students more than a straight only physical lab does.*

Faculty members who taught using Beyond Labz reported that most students found the platform accessible, while 5% of students did not have access to labs due to technical issues. One faculty member expressed concern that the reason could be that "*students may not have adequate hardware*".

Beyond Labz users needed to install the software on their computer, giving users access to both Desktop and Web versions of the platform. An Internet connection was required to login to the platform, but after that, the labs could be used without Internet. The age and model of a computer or absence of a laptop were some issues reported by students. Learners who did not have access to the resources were given alternative individual or group assignments.

Based on faculty member feedback, the accessibility of a virtual STEM platform and its compliance with WCAG 2.0 (W3C Web Accessibility Initiative, 2021) should be considered during adoption, and plans made for accessibility gaps. Participating instructional designers raised concerns about the Accessibility for Ontarians with Disability Act (AODA, 2005) compliance of Beyond Labz because the tool was originally designed to prioritize realism over accessibility. However, all current and new lab designs are closely aligned to and guided by WCAG 2.0 AA standards (Accessibility Conformance Report, 2020).

Virtual Labs Have the Potential to Enhance Learning

Faculty members reported that the platform can be a useful supplement to real labs, especially for online learning, as it prepares students to apply experiments in real life, after exploring different virtual possibilities and options. One faculty member stated: "*Students can learn to run an experiment, make mistakes, and practice developing critical thinking and problem-solving skills before getting to the "wet" lab."*

Faculty members appreciated "*lots of choice and the fact that they are virtual*" and the "*ability to play with equipment*" in VLs. They explored options for different experiments that could be administered on the platform. One participant described their experience with Beyond Labz as "*no auto-pilot feeling*". The VLs encouraged students to become active learners benefiting from their curiosity and the ability to learn from mistakes. "*They can change/adjust the values for the different variables and compare the results, they can also have recorded results as well".*

Beyond Labz allows students to do science in online courses. As one faculty member wrote, "*Beyond Labz adds a valuable tool to teach the process of science along with the concepts".* Importantly, this tool may be more valuable for general education science college courses ("*with the right faculty training*" as one participant noted) that teach science literacy and do not have restrictive content requirements of applied science college courses. According to one faculty member, "*I would use it for pre-lab activities as well as stand-alone activities and demonstrations*".

Successful Virtual Lab Integration Requires Instructional Support for Students and Faculty

Faculty member feedback emphasized the importance of structured online learning and the need to develop detailed lab manuals to understand how to effectively use VLs. One faculty member pointed out that Beyond Labz is "*not an intuitive platform*", and another confirmed that "*Without a proper tutorial, the interface appears overwhelming and hard to follow*." Another suggested, "*I think a lot more scaffolding and gradual easing into the software is required in the online space*." Another suggested that support is needed for both faculty and students as some students "*want to have someone holding their hand through every step"*.

Implementing Virtual Labs Presents Some Barriers

Many college faculty members are hired because they are professionals in their field. Often, they do not have skills and knowledge in instructional design or special training on VLs in teaching and learning contexts. Time and effort are required to learn new resources. One faculty suggested, *"There is a lot of time and effort that needs to be invested to use these Labz and integrate them into the courses, for the Labz to appear seamless."* Another barrier identified *"The learning curve for creating your own experiments and fear of the unknown"* and concern to "*find balance between direct instructions and real time experience*" was also expressed. Moreover, one participant wrote, "*the perceived level of student support may scare some faculty away from using* [Beyond Labz]*"*.

It is Essential for Faculty Members to Develop Digital Literacy Skills

Bates (2022) emphasized that Canadian colleges and universities need skilled teachers to teach learners the skills needed in the 21st century. Also, it is important to equip learners with the science skills and competencies needed in the digitalized world (Hazelkorn et al., 2015). There is well-established literature and generally agreed best practices (Bates, 2010), but Christensen Hughes and Mighty (2010) found that many faculty members are unaware of these standards. One participant mentioned that a lack of digital skills might be the reason for "*faculty not engaging with the platform*". Many participants agreed that this tool develops creativity in teachers. One participant responded, "*Creative thinking - motivated me to continue to push forward to find technology that supports the pedagogy and curriculum I am working on*".

To fully benefit from using the Beyond Labz platform, participants agreed that faculty members need to upgrade their technology skills to be able to create their own virtual lab content, which will align with course outcomes and serve learners' needs. One faculty member responded, "*I think a lot of teacher training might be required before it is widely adopted*".

Unintended Consequences

One significant finding was the realization of the importance of teamwork. The Professional Learning Community on Microsoft Teams created for the project supported the sharing of ideas, concerns, and various teaching and learning resources, the development of digital literacy, and the building of relationships among participating faculty members. This community was a great way to connect with managers, instructional designers, and other interested faculty members. Members agreed that *"Training on the software and development of custom activities requires time, resources and commitment from their Chairs."*

Recommendations

Recommendations support previous academic research. It is important for faculty members to enhance their media literacy skills and explore different educational platforms (e.g., Gamage et al., 2020). The key is to make the process enjoyable for all educational stakeholders and provide opportunities for peer collaboration. Creating a community of practice within an educational institution is another option for sharing ideas and informal training (Alves et al., 2016). Although opportunity to create a larger community of practice outside a single school may be valuable. In agreement with previous research (e.g., Lima et al., 2019) facilitating ongoing support for faculty members by providing initial training, instructional support, and sharing best practices and activities is needed. It is worth mentioning that resource costs and lack of institutional support may be a barrier to adoption. To find a solution, stakeholders, faculty members, administration, and students should work together to make evidence-based decisions.

Implications

Virtual laboratories and simulations are designed to supplement an already well-designed curriculum and teacher efforts, but they cannot replace them (Perkins et al., 2010). Stöter et al. (2014) suggest research continues to support the adoption of tools that meet the criteria for effectiveness and efficiency in learning experience and outcome. This study contributes to faculty PD literature by unpacking college faculty member perceptions of the efficacy of science VLs and the factors contributing to successful curriculum implementation.

This study offers insight into the implementation process of virtual science labs and identifies the benefits and challenges of using virtual science labs from a faculty member viewpoint. It aims to improve science-education stakeholder knowledge when searching for tools to serve student, faculty member, and institutional needs, and urges more studies to explore the impact of VLs on faculty PD and student learning.

This study demonstrates that with peer support and guidance college faculty may successfully integrate science virtual labs into their courses. For many, teaching with VLs will require stepping outside their comfort zone and experimenting with new teaching techniques. Institutional and provincial support cannot be understated. Preliminary findings suggest that VLs may not be suitable for science courses in vocational programs such as dental or nursing programs because of the intensive nature of these applied programs and the financial cost to the student for such a resource.

This research area is relatively new. There has not been enough data collected to be able to develop a framework for best practices, both in terms of development and VLs use (Brinson, 2017). As a result, it may be difficult to get institutional support for using VLs without evidence to support educational advantages for both faculty members and learners. Deeper exploration of faculty needs for introducing new tech tools into STEM teaching is required.

Three limitations are acknowledged. First, the narrow scope of the study setting. This study takes place in one polytechnic institution in Ontario and may not be representative of other postsecondary institutions in Canada. Beyond Labz may have a greater uptake at the university level due to the nature of their academic and specialist programs and students. Although, colleges of applied arts and technology are focused on career training and trades. Second, the small participant number may limit the transferability or applicability of the findings. The final limitation lies in the probability of the ongoing pandemic affecting both faculty member and student performance and impressions. A long-term research study may provide further insight by allowing for greater knowledge of the context or natural setting, testing different virtual lab vendors, detailing participant backgrounds and experiences, and in turn, opportunities for deeper analysis.

To our knowledge, this study is the first study to analyze the efficacy of virtual labs for science courses at polytechnic institutions in Canada. It addresses the growing need for online formats and is aimed at improving the knowledge base of science education stakeholders. Specific approaches to the integration of VLs needs to be studied to increase their effectiveness. The COVID-19 pandemic has been an important teaching moment for educators around the world that should inform the future design of learning environments and teacher PD, post-pandemic. While apprehension of new technology may cause some teachers to shy away from VLs, the educational advantages offered by this learning platform outweighs initial fears. In addition, the affordances of VLs can address issues around artificial intelligence use in education and academic integrity by providing opportunities for active learning and designing of authentic assessment.

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Appendix A: Faculty Pre-survey

1. Please provide some background information on your years of teaching experience.
2. What science virtual labs would you like to test? Select everything that apply.
   a. Biology
   b. Chemistry
   c. Organic chemistry
   d. Physical science
   e. Physics
3. How familiar are you with virtual labs and/or simulations?
   a. Not at all familiar
   b. Not so familiar
   c. Familiar
   d. Very familiar
   e. Extremely familiar
4. What virtual labs or simulations do you currently use in your courses, if any? Write the name of the resource and ways you use it in the classroom.
5. Do you have a network of teaching colleagues (i.e., a community of practice) to share/reflect with on best practices and generate novel, creative ideas for incorporating.
   a. Yes
   b. No
6. What are your own professional learning goals in participating in this pilot?

Appendix B: Faculty Post-survey

Introduction

1. How familiar are you with virtual labs and/or STEM simulations?
    a. not at all familiar
    b. slightly familiar
    c. moderately familiar
    d. very familiar
    e. extremely familiar
2. How important are virtual labs for STEM general education courses?
    a. Unimportant
    b. Slightly important
    c. Moderately important
    d. Important
    e. Very important
3. What are some of the virtual labs and/or simulations you use the most?
4. What do you like or dislike about these resources?
5. How often do you currently use virtual labs and/or simulations in the courses you teach?
    a. Never
    b. Rarely
    c. Sometimes
    d. Often
    e. Always
6. Please provide some examples of how you use virtual labs and/or simulations in your courses. For example, as pre-lab activities, wet lab replacement, etc.

Beyond Labz Specific Questions

7. What virtual labs did you try?
8. Rate your overall experience with Beyond Labz
    a. Very poor
    b. Poor
    c. Fair

   d. Good
   e. Excellent
9. What did you like most about them?
10. What did you like least about them?
11. Comment on overall quality of this resource for STEM college courses
   a. Very poor
   b. Poor
   c. Fair
   d. Good
   e. Excellent

Opportunity Questions

12. Beyond Labz virtual labs is a good way to engage students with science exploration.
   a. Strongly disagree
   b. Disagree
   c. Neutral
   d. Agree
   e. Strongly agree
13. Would you use this product today?
   a. Definitely not
   b. Probably not
   c. Possibly
   d. Probably
   e. Definitely
14. How might you integrate the Beyond Labz STEM virtual labs into your courses? Provide examples of activities.
15. What might keep faculty from using Beyond Labz virtual labs?

Reaction Questions

16. What is the most appealing about Beyond Labz virtual labs?
17. What is the hardest part about using this resource?
18. Was there anything surprising or unexpected about this resource?

19. What could be done to improve this product?
20. Was there anything missing from this product that you expected?

User experience

21. The resource has a user-friendly interface.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
22. The resource is easy to navigate.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
23. The resource support/help is effectively organized.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
24. The resource pages generally have good image quality.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
25. The resource has pleasing appearance.
    a. Strongly disagree
    b. Disagree

c. Neutral
d. Agree
e. Strongly agree

26. The resource has real wet lab feeling to it.

a. Strongly disagree
b. Disagree
c. Neutral
d. Agree
e. Strongly agree

Appendix C: Student Post-survey

Introduction

1. How familiar are you with virtual labs and/or STEM simulations?
    a. Not at all familiar
    b. Slightly familiar
    c. Moderately familiar
    d. Very familiar
    e. Extremely familiar
2. How important are virtual labs for STEM general education courses?
    a. Unimportant
    b. Slightly important
    c. Moderately important
    d. Important
    e. Very important
3. What are some of the virtual labs and/or simulations you have used in your college courses?
4. What do you like or dislike about these resources?
5. Have you worked with virtual labs and/or simulations in other courses this semester? If yes, then explain.

User experience

6. The resource has a user-friendly interface.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
7. The resource is easy to navigate.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree

    e. Strongly agree

8. The resource support/help is effectively organized.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
9. The resource pages generally have good image quality.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
10. The resource has pleasing appearance.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree
11. The resource has real wet lab feeling to it.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree

Reaction Questions

12. What is the most appealing about Beyond Labz virtual labs?
13. What is the hardest part about using this resource?
14. Was there anything surprising or unexpected about this resource?
15. What could be done to improve this product?

16. Beyond Labz virtual labs is a good way to engage students with science exploration.
    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly agree

Beyond Labz Specific Questions

17. What virtual labs did you try?
    a. Biology
    b. Chemistry
    c. Physics
18. Rate your overall experience with Beyond Labz
    a. Very poor
    b. Poor
    c. Fair
    d. Good
    e. Excellent
19. What did you like most about them?
20. What did you like least about them?

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Generative Artificial Intelligence in Graphic Design Education: A Student Perspective

L'intelligence artificielle générative dans l'enseignement du graphisme : Le point de vue d'un étudiant

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Abstract

Generative Artificial Intelligence (GenAI) is re-defining the way higher education design is taught and learned. The explosive growth of GenAI in design practice demands that design educators ensure students are prepared to enter the design profession with the knowledge and experience of using GenAI. To facilitate GenAI's introduction in a project-based context, it is suggested that design educators use critical engagement as a starting point to assure students understand the strengths and weakness of GenAI in the creative design process. There is little guidance on how to systematically integrate GenAI in design studio practice while maintaining a critical perspective of the ethical issues it has engendered. This research explores student attitudes toward GenAI, frequency of its use, and student perception of its impact on their future design careers. A survey of a representative cohort of graphic design students (n = 17) reveals a pragmatic acceptance that GenAI will change how design is practiced and a concurrent willingness to learn more on how to use it effectively and ethically. The survey validates the need for design educators to engage and guide students critically in their understanding and use of GenAI within studio and professional practice.

Keywords: artificial intelligence, AI integration, design curriculum, generative AI, graphic design, graphic design education, student attitudes

Résumé

L'intelligence artificielle générative (GenAI) redéfinit la manière dont la conception de l'enseignement supérieur est enseignée et apprise. La croissance explosive de la GenAI dans la pratique de la conception graphique exige que les éducateurs s'assurent que les étudiants sont préparés à entrer dans la profession de concepteur graphique avec les connaissances et l'expérience de l'utilisation de la GenAI. Pour faciliter l'introduction de la GenAI dans un contexte de projet, il est suggéré que les éducateurs utilisent un engagement critique comme point de départ pour s'assurer que les étudiants comprennent les forces et les faiblesses de cette intelligence dans le processus créatif de conception. Il y a peu de directives sur la manière de l'’intégrer systématiquement dans la pratique du studio de conception tout en maintenant une perspective critique sur les questions éthiques qu'elle a engendrées. Cette recherche explore les attitudes des étudiants envers l’intelligence artificielle, la fréquence de son utilisation et la perception des étudiants de son impact sur leur future carrière de concepteur graphique. Une enquête auprès d'un groupe représentatif d'étudiants en conception graphique (n = 17) révèle une acceptation pragmatique du fait que la GenAI changera la manière dont la conception graphique est pratiquée et une volonté concomitante d'en apprendre davantage sur son utilisation efficace et éthique. L'enquête valide le besoin pour les éducateurs d'impliquer et de guider les étudiants de manière critique dans leur compréhension et utilisation de la GenAI au sein de la pratique en studio et en milieu professionnel.

Mots-clés: attitudes des étudiants, conception graphique, éducation en conception graphique, IA générative, intégration de l'IA, intelligence artificielle, programme de design

Introduction

Generative artificial intelligence (GenAI) is the latest technology to profoundly disrupt design practice and education. GenAI is viewed by some as the most disruptive technology ever introduced to society, business, and education (Pavaloaia & Necula, 2023). Given this reality, design educators need to discover ways to include GenAI in their curriculum based on changing roles within the design profession that will require less technical know-how in design domains such as graphic design and more collaboration and digital curator skills. Kauppinen and Sivula (2023) observe, “Universities have a role in both educating and being forerunners both for and with society” (p. 265).

The use of GenAI in design education is still in its early stages. Forward thinking design educators have begun implementing artificial intelligence (AI) platforms in a limited way and are beginning to formulate how to ethically incorporate GenAI’s use in design education (e.g., Fleischmann, 2024; Huang et al., 2023; Yang, 2020). There are few guidelines about how to integrate this rapidly developing technology especially given its well-known ethical challenges of plagiarism, copyright infringements, and embedded bias in its programming that produces mistakes (DeBrusk, 2018; Solly 2019). Although universities have hastily assembled policies governing AI’s general use and warned of its unaudited problems (e.g. Griffith University, 2023), design educators are confronting the need to integrate GenAI practice into their curriculum due to its rapid adoption in the design industry (Hommés Studio, 2023; Kaiko, 2023).

This is not the first time that technology has disrupted how design is practiced, taught, and learned (Fleischmann, 2013, 2015). Two relatively recent examples stand out. Manual tasks in the printing industry were replaced by digital processes when desktop publishing debuted, pioneered by word processors in the 1970s. Similarly, the Internet dramatically changed how people communicated, shopped, planned, and socialised, with designers constructing and facilitating these new forms of communication and interaction. Each new technology shift led to radical changes and specializations emerging in the design profession. For example, User Interface (UI) and User Experience (UX) design emerged with the Internet while GenAI is introducing prompt engineering as a new design skill. The historical arc of design as a hands-on craft in the creation of visual works has co-evolved with digital technology into its current fluid state of interacting with hyper-fast databases which assume the role of creative iteration – once the sole provenance of graphic designers.

The challenge for design educators is to ensure that design students maintain and develop their creative mastery in the graphic design process while simultaneously educating design graduates to be conversant with GenAI processes demanded by the industry. Kauppinen and Sivula (2023) see that students and educators need to work *together* to "fully comprehend the changes currently taking place in the higher education sector" (p. 270). An attempt to help facilitate such collaboration between design educators and students in the use of GenAI is the purpose of this study. This research therefore aimed to explore graphic design student attitudes toward GenAI in the context of its rapidly expanding use in the design profession to help guide design educators towards its integration in the classroom. A pragmatic approach was integral to this study and included collecting quantitative and qualitative data from 17 undergraduate graphic design students through a survey. Findings showed that students have an open attitude towards the use of GenAI as part of their future careers.

Historical Context: Design Automation

Artificial intelligence is part of the historical trajectory of technology that transformed livelihoods, society, and subsequently fuelled suspicion and angst. Mechanophobia–the fear of machines–is a prime example of this resistance to technological change. Mechanophobia was born during the Industrial Revolution when machines took over manufacturing processes. In the 1830's, for example, the silk design textile industry was revolutionised in Lyon, France by the Jacquard loom, which was automated by a chain of punch cards, a precursor to the computer age (Wikipedia, 2024c). Artificial intelligence has assumed a similar role as the Industrial Revolution's Jacquard looms, which replaced people with automation. Artificial intelligence's omnipresence in society and education is tinged with a similar fear of its uncontrollable sweep which is raising some concerns that AI will replace people in some design jobs (Meron, 2022; Taylor, 2023) but will not dominate humankind as visualised in popular films and literature.

There are many definitions of AI, such as the one proposed by Monostori (2019) which defines AI as computer programs that behave like humans in their problem solving and adaptability. This idea that machines can mimic the human brain has been studied for decades. Machine learning and intelligence were put to the test in 1950 when British mathematician and computer researcher Alan Turing (1950) wrote his seminal paper, *Computing Machinery and Intelligence*. In that paper, Turing posed the question, "*Can machines think?"* To answer that question, Turing invented the *Imitation Game*, where a human had to determine if the answer to a question was generated by a machine or a person (Wikipedia, 2024a). Turing died in 1954 long before IBM's supercomputer, Deep Blue, beat world class chess champion Gary Kasparov in 1996 with its ability to calculate up to 21 moves (Wikipedia, 2024b). There is little doubt that Turing would have been astounded by the advancements in AI that have swept the world since the Imitation Game, particularly when a Large Language Model–ChatGPT–burst into public consciousness in November 2022. ChatGPT (developed by OpenAI) is arguably the best-known GenAI platform that can seemingly answer any question posed instantaneously, although ChatGPT and its image-creating counterparts are often criticised for producing mistakes (Rees, 2023). How does GenAI fit within the broader definition of AI? Marr (2023) notes that GenAI has the ability to create independent outcomes such as images, text, and video rather than perform a discrete set of mathematical tasks. GenAI is trained to recognise patterns in user requests or prompts which trigger the platform to produce seemingly original and creative products.

As GenAI evolves, it is reshaping how design is practiced (Gibbons & Moran, 2024). Although GenAI is also being employed in other domains such as interior design and product design (Bartlett & Camba, 2024), it is particularly predominant in graphic design.

The central role of GenAI in the evolution of design practice centres on automated processes that signal an information age revolution analogous to the Jacquard loom. The truly revolutionary aspect of GenAI within design practice is its capacity to generate text and images from a simple text-chatbot interface. Image-generating platforms such as Midjourney and DALL-E produce artificial images, photographs, and design solutions based on a user written request (prompt) in a chatbot dialog format. These platforms can generate creative outputs which imitate any designer, any style period, or combined to create new outcomes. Text generating platforms such as ChatGPT (version 3.5) function in the same way but create text-based information/solutions (Guinness, 2023). GenAI platforms can also be engaged for tasks such as video synthesis, automated translation, code generation, scripting, etc. (e.g., Sun, 2024).

Critics of GenAI in design practice and education worry that its implementation in the design profession will render some roles–such as graphic designer–obsolete (Matthews et al., 2023; Meron, 2022). As Bearman et al. (2022) observe, "AI could have real impact upon labour markets and thus higher education. Therefore, AI is not just a matter for technological innovation but also represents a fundamental change in the relationship between higher education and broader socioeconomic interests" (p. 370).

That said, GenAI has its advocates in the educational sector such as Braue (2023) who states, "Students must be engaged in the normalisation of generative AI within schools and universities" (p. 1).

AI in Higher Education

The use of AI in education has been studied for almost four decades. Wenger (1987) explored the interaction between computational mechanisms and cognitive functions, emphasizing the role of AI and machine learning in facilitating knowledge transfer. Wenger already observed the importance of educator meditation when using AI programs, noting that AI programs largely ignored human expertise, an absence which is still being noted in GenAI (Zawacki-Richter et al., 2019). Zawacki-Richter et al. concurred with Wenger that AI needed guidance from tutors to make sure learning objectives were achieved to be implemented successfully. Pinkwart (2016) stressed that teachers need to be trained on how to use the new technology otherwise they are "less likely to use it" (p. 774).

Early research on GenAI in higher education focused more on generalised descriptions while specific prescriptions for its use are slowly emerging. In fact, initial literature reviews about the use of

AI in higher education found that the very term *artificial intelligence* is used in a vague and circular manner within higher education journals without in-depth discussion with its stakeholders. Bearman et al. (2022) addressed the dilemma by giving a working definition of AI's wide reach: "AI in higher education encompasses an assemblage of data, different kinds of software, bureaucracies and corporations that sometimes include and sometimes exclude teachers, students and administrators" (p. 381). Zawacki-Richter et al. (2019) identified four key areas of how GenAI's is currently used by administrators and educators which are (a) assessment and evaluation, (b) profiling and prediction, (c) intelligent tutoring systems, and (d) adaptive systems with personalization.

Several articles list how AI is changing the shape of higher education by simulating teachers through Intelligent Tutoring Systems (Schiff, 2021). Crompton and Burke (2023) found that AI was mainly used for student assessment, managing student learning, as well as automated tutoring which adjusts student activities and strategies based on their individual needs. Grassini (2023) envisions a bright future for AI in the classroom. She cites ChatGPT as a tool to help educators with assessments and lesson plans thus decreasing educator workload. Despite the potential pedagogical opportunities, in a wide-ranging assessment of the future of GenAI in education, the UNESCO report (Miao & Holmes, 2023) states that more studies need to be done on GenAI's psychological and social impact on students.

GenAI in Design Education

There is a big difference, however, between automated tutoring systems and GenAI used by designers. The latter can produce thousands of variations of images and designs through simple prompts which are written instructions or questions from users. Design educators anticipate that GenAI will reshape the designer's role, necessitating new skill sets in design graduates (Davis, 2023; Gilbert, 2023; Yeo, 2023). These new design skills broadly align with those identified in The Future of Jobs Report 2020 (World Economic Forum, 2020): analytical thinking, complex problem-solving, critical analysis and creativity, originality, and initiative. Specific to graphic design, Matthews et al. (2023) identified "a move…toward a deeper engagement with the human skills associated with negotiation, facilitation and judgement" (p. 2). The human-centric skills are central to design's studio pedagogy. This stance was corroborated by the student attitudes toward GenAI presented in this study. Design educators are also starting to recognize the importance of teaching skills aligned with GenAI, leading to discussions on integrating programming skills into design classes (Offenhuber & Mountford, 2023) as well as prompt engineering (Bamford, 2023; Dubberly & Pangaro, 2023). Others such as Cain and Pino (2023) advocate for the preservation of the human touch in design education amid the technological advancements. The question is how to introduce and integrate GenAI effectively.

The limited literature regarding AI utilization in design education offers minimal guidance on a systematic approach to teaching fundamental design studio concepts. Concerns related to issues such as plagiarism, copyright violations, and the perpetuation of racial stereotypes challenge the unbridled integration of GenAI (Auernhammer, 2020; Morrone, 2024; Ray, 2023). However, researchers recognize its potential as a transformative technology in design. Figoli et al. (2022) studied design students' reliance on AI tools in a project-based assignment, observing their interaction and trust in AI platforms. The educators discovered that the majority of design students believed AI was valuable in initial brainstorming but not essential in the final design process.

In the course *Designing AI Products and Services*, Carnegie-Mellon University's syllabus (Yang, 2020) which is freely available, includes a basic understanding of how AI works as well as hands-on experience in its use as a "design material". The course, which was taught at the University's Human-Computer Interaction Institute, also addressed ethical issues using AI, such as discrimination. The Carnegie-Mellon course is the result of forward-thinking instructional design recognising the need to incorporate advanced technology in design education to introduce disruptive technology tools from a critical perspective.

The importance of a critical perspective in teaching GenAI cannot be overstated. Fleischmann (2024) introduced a systematic approach to incorporating the use of GenAI in an undergraduate design curriculum using a project-based assignment, which was undertaken after students discussed the ethical concerns of using GenAI in design. In her work, the author asked students to reflect on their experiences and found that many were sceptical about GenAI's creative abilities and expressed disappointment about its mediocre output. Fleischmann (2024) concluded that students who use GenAI may be sidestepping the quintessence of the creative process which involves grappling with conceptual challenges, experimenting with diverse ideas, and confronting obstacles in translating abstract concepts into tangible visual forms. In return, they may miss out on deeper learning experiences and lack the confidence that comes from navigating to find their creative voice.

Huang et al. (2023) propose an innovative approach to design education that goes beyond traditional AI concepts and practices. They advocate for an experiential exploration of AI knowledge and skills, fostering creative and aesthetic integration with AI in future scenarios. The emphasis is on combining personal and societal perspectives within course design to encourage a holistic understanding of designing with AI. On a practical level, they highlighted assessment as a challenge and suggested evaluating a blend of intuitive, forward-thinking creativity and a reflective, critical approach to understanding design iterations.

In the few previous studies, design educators viewed GenAI as an inevitable part of design curriculum that should be tempered by its limitations. As GenAI's use in society and the design profession becomes more widespread, its benefits and shortcomings are surfacing in academic discourse. Design educators in Germany, for example, are worried about GenAI replacing graphic designers (Fleischmann, 2023). In fact, job losses are a widely mentioned concern among design educators (Matthews et al., 2023; Meron, 2022). Some design educators, like Yeo (2023) take a pragmatic approach to introducing AI to students: "These digital buzzwords are here to stay whether we like it or not, so faculty members need to be digitally literate to provide capabilities beyond emerging technologies such as AI, the Internet of Things, and data science" (p. 229).

Automation vs. Creativity

One of the hallmarks of GenAI is automation, based on algorithms which translate user written prompts into visual or written results. GenAI models are trained on datasets, identifying patterns to generate new data that mimics the original training set (Marr, 2023). An example is logo design. Once a paid-for service employing design professionals, it can now be undertaken using GenAI platforms–a process the majority of students in this study explored a trimester earlier. The logo design process can take minutes using GenAI, compared to hours if drawn by hand. GenAI logo makers operate by using a simple fill-in form:

Step 1: input the [business name] and [slogan] (Figure 1)

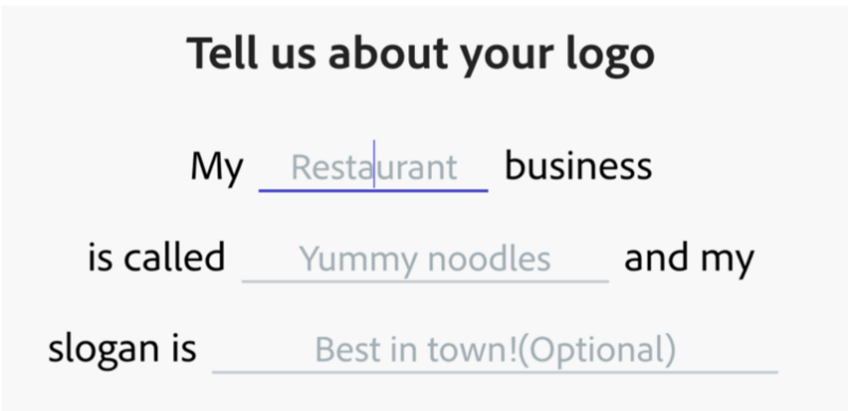
Step 2: select a ‘style’ such as ‘elegant’ or ‘modern’ (Figure 2)

Step 3: select a ‘colour theme’ (Figure 3)

Step 4: press ‘create my logo’ button which provides a multitude of logo designs

Figure 1

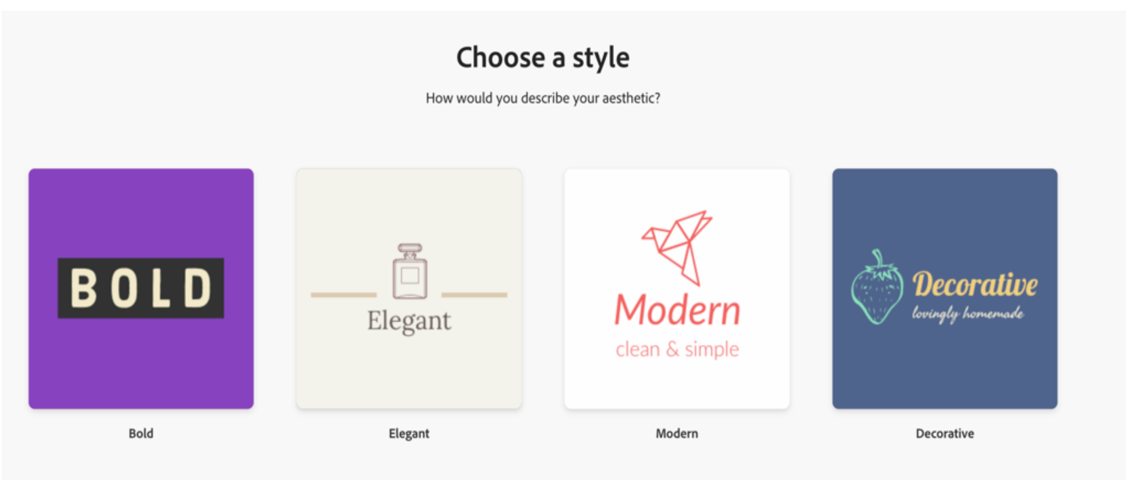
Input Prompts for Logo Design



Note. Adobe Express Logo Maker, https://www.adobe.com/express/create/logo

Figure 2

Logo Style Selector



Note. Adobe Express Logo Maker, https://www.adobe.com/express/create/logo

Figure 3

Colour Theme Selector

Note. Logo.com, https://app.logo.com

The ease and speed of logo generation via fill-in form and colour palettes essentially eliminates the rigorous and iterative process that students undergo during the creation of graphic design projects. While it is not guaranteed that the outcomes created by GenAI platforms are always usable (Fleischmann, 2024), it can be argued that they strip away one layer of uncertainty needed to develop student's creative potential. As Kelly (2023) and others (e.g., Orr & Shreeve, 2018) highlight, uncertainty and ambiguity are central pillars in design education, which is characterized by encouraging students to navigate anomalies, overcome design hurdles, and refine their ideas through continuous experimentation and critique.

Research Methods

This study followed a pragmatic research paradigm, recognizing that knowledge is socially constructed and rooted in interconnected experiences (Kelly & Cordeiro, 2020; Morgan, 2007). To gauge student responses to GenAI, the author surveyed undergraduate graphic design students, some of whom had previously discussed its strengths and weaknesses in a class setting before starting their projects. In this study, design students were asked to speculate on the future of GenAI in the design profession and its impact on their job prospects. A survey was used to explore the perceived strengths and challenges of using GenAI, and to measure the impact of an educator-guided overview of GenAI through classroom discussions.

To comprehend design student perspectives on the integration of GenAI into the curriculum, the researcher sought insights from 17 second-year undergraduate students majoring in graphic design as part of a Bachelor of Design program. Applying a pragmatic research paradigm enabled the researcher to select a method that suited the real-world practice nature of the situation (Creswell, 2008; Punch, 2009). Therefore, an online survey was deemed most suitable to collect data in an efficient manner (Wright, 2005). The survey, conducted through an online tool (Survey Monkey), gathered both quantitative and qualitative data. Survey questions delved into students' utilization of GenAI, its impact on the design profession, and the perceived advantages, challenges, or limitations thereof.

The researcher crafted the survey questions to first gather a broad overview or trend on the topic using closed-ended questions and then elicited more detailed insights with open-ended follow-up questions. This approach yielded data on measurable indicators (e.g., *How do you perceive the impact of AI tools on the design profession?* Answer choices: *Positive, Neutral, Negative*) and also provided deeper understanding of the studied phenomena through qualitative feedback (e.g., *Please explain your answer. Why do you feel positive/negative/neutral?*). Furthermore, answer options for the two multiple choice questions that inquired about the perceived advantages and disadvantages of GenAI in the design process, linked directly to industry practice realities reported in existing research (e.g., Gilbert, 2023; Huang et al., 2023; Meron, 2022). The specific survey questions are included in the Findings and Discussion section.

The general approach to data analysis was inductive and had an overall drive of exploration and discovery (Morse & Niehaus, 2009). For the analysis of the quantitative data, SurveyMonkey delivered basic statistical data including the tally of response totals, percentages, and response counts. Qualitative data analysis involved categorizing comments into two overarching themes (Kiger & Varpio, 2020), namely benefits and challenges. In presenting student perspectives, qualitative feedback was employed to enhance the quantitative findings, providing a deeper understanding of the situation (Fielding, 2012; Rossman & Wilson, 1985).

Although small by statistical standards, the participant numbers represent a sample size congruent with the size of design classes taught in a traditional design studio environment. The researcher is aware that the small sample size limits the generalisability of findings but rather presents real-time in-class perspectives on attitudes which reflect students' experience.

Findings and Discussion

Impact of GenAI on Design Careers

Survey responses clearly indicate that students do not view GenAI as a threat to their future career goals. The survey asked students to speculate about their future jobs in the design profession in five years' time. Fourteen students expressed a desire to be graphic designers, whether working as a freelancer in a creative studio, or by setting up their own business. Additionally, another student aspired to be a font designer while another aimed to merge their design skills with film and TV. One student was unsure but commented on a wish to do "something creative either producing digitally or physically". The students did not see GenAI threatening their hopes of becoming employed; a concern that some design educators have expressed about the use of GenAI in the graphic design profession (Fleischmann, 2023; Matthews et al., 2023; Meron, 2022). Students seemed confident in their professional design future despite a large majority (82%) agreeing that GenAI will replace certain aspects of traditional design work. While 6% predicted this replacement will largely happen; the remaining students (12%) saw GenAI as complementary to traditional design work. This confidence that their job futures were not threatened by AI was also reflected in the student comments. One student remarked, "AI will not replace human designers. It will enhance the design process and maximise people's creativity."

Student Use of GenAI

The use of GenAI in the design profession has increased significantly since its pioneering inception. Companies are now employing GenAI, particularly in the iterative process (e.g., Wernersson & Persson, 2023), which indicates that students need to be familiar with its basic use. The survey asked students if they had ever used AI-powered design tools for university projects prior to the trimester. The majority (70%) had used GenAI occasionally, while roughly a quarter (24%) said they had never used AI but were interested in learning more about it. Only one student was not interested in using GenAI.

Advantages and Disadvantages of Using GenAI

Students were asked to identify the main advantages and disadvantages of using GenAI. More than three-quarters of the respondents (76%) cited *improved efficiency in design tasks* as the major advantage of AI and more than 80% said *AI enhances creativity and inspiration*. More than half of the students (53%) agreed that AI gave them *access to data analytics and insight*. Roughly a third (35%) cited *customization and personalization of designs* as an advantage. No student selected *I don't think there are advantages* from the survey.

When exploring the disadvantages, almost all survey participants (94%) agreed that ethical challenges were the main problem with using GenAI, particularly *stealing or copying work and creative styles*. Other considerable concerns cited by a majority of students (82%) were the *loss of the human touch and creativity* and AI's *limited ability to understand and interpret human emotions and aesthetics*. These responses from students who previously discussed GenAI's problems before using it concur with design educators who cite the same concerns about GenAI's inability to mimic creative approaches to design problems and its error-prone results (Fleischmann, 2024; Huang et al., 2023). Overall, those student responses–both pros and cons–reflect an awareness of the creative shortcomings of GenAI and how to use GenAI without crossing an ethical boundary. This reflects a key learning objective in raising awareness that students need to be responsible for their own actions, decisions, and initiatives during the creative process.

Pragmatic Acceptance – Future Integration

When exploring the openness of students to engage with GenAI technology as part of their design studies, 82% of survey respondents said they wanted to learn more about how to use GenAI tools in the design process, two students (12%) would need more information, and one student (6%) was not interested and preferred learning about traditional design methods only. These findings indicate firstly, an appetite among this design student cohort to learn more about using GenAI in the design process and secondly, a pragmatic acceptance that GenAI will be part of their professional future and should be consequently in their design education. As this student expresses: “I believe that AI will be integrated into our daily lives and it has already to a degree, so the best we can do is accept it and try and be educated and learn about it.”

A clear direction is given by this student for GenAI integration: “I believe that there will be a big emphasis on educating students regarding how they can use AI appropriately and ethically in design rather than just focusing on how they can utilise it for effective workflows.” Another student sees GenAI as part of the future of the design profession but cautions against its overuse in learning the critical skills of design:

> As AI becomes integrated into design as a profession, it will subsequently become part of design education. The main reservation I have about this is if AI tools are too heavily relied on by new design students, they may not learn how to undertake certain processes without the aid of these tools.

Conclusion

GenAI is neither a dystopian nor utopian advancement in technology. Like all technology breakthroughs, it is a change agent particularly in higher design education. The findings reveal that students have open attitudes toward using GenAI, however they may have limited experience using GenAI platforms and require further training in its responsible use.

This study validates a critical approach to introducing GenAI as a potentially valuable technology tool that links students to current industry demands, while fostering their creative development. Given this approach, design educators have a responsibility to learn as much as they can about GenAI before teaching its basics from a critical standpoint. This is especially evident when approaching GenAI from an ethical standpoint and revealing its potential to generate inaccurate and discriminatory outcomes.

The central tenet of this approach is: Graphic design students must still possess strong design skills such as visual communication and creative problem-solving while also developing new skills, like prompt engineering. Design educators need to help students to cultivate a critical eye to question the authenticity of images and text generated by GenAI, and most importantly, view it as a digital collaboration tool, not a manufacturing hub for final products.

While the demand in industry will guide design curriculum development, higher education institutions will continue to update their GenAI policies and should take a proactive role in providing educators with opportunities to build this new technological knowledge. As economies increasingly turn to technologies like GenAI to increase efficiency, there will be an ongoing debate about its role in the creative process, which is essentially a human activity. Reconciling these two opposing viewpoints should be the subject of further discussion and research into GenAI’s impact on design education.

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Recréer le territoire de l'école par la cocréation de maquettes

Recreate the School's Territory by Co-Creating Models

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Résumé

Le rapport des élèves à l'espace peut se développer par le biais de différentes activités d'apprentissage. Parmi ces activités, le projet *SmartCityMaker* engage les élèves dans une démarche de cocréation de leur quartier scolaire par le biais de la réalisation d'une maquette combinant les techniques analogiques et numériques. Dans le cadre de cette étude, les élèves d'une école primaire sont invités à explorer différentes facettes de leur territoire de proximité et, par la suite, à mobiliser leurs habiletés spatiales de manière pratique par la construction d'une maquette. L'étude cherche à comprendre la manière dont le projet *SmartCityMaker* permet d'enrichir le rapport des élèves à leur territoire scolaire, ainsi que leur pensée spatiale. Dans cette visée, nous analysons le processus d'apprentissage vécu par des élèves de 11 ans d'une école primaire en France qui participent au projet *SmartCityMaker*. Nous présentons la démarche d'apprentissage vécue par les élèves et les aspects pouvant permettre d'observer leur rapport à l'espace de même que la manifestation de leur pensée spatiale.

Mots clés : cocréation, maquette, pensée spatiale, *SmartCityMaker,* territoire

Abstract

Students' relationship with space can be developed through a variety of learning activities. Among these activities, the *SmartCityMaker* project engages students in the process of co-creating their school district through the creation of a model combining analog and digital techniques. This study invites elementary school students to explore different facets of their local area and then mobilize their spatial skills in a practical way through the construction of a model. The study seeks to understand how the *SmartCityMaker* project enhances students' relationship with their school territory, while enriching their spatial thinking. We analyze the learning process experienced by 11-year-old students from a French elementary school participating in the *SmartCityMaker* project. This study presents the learning process experienced by the students and the aspects that enable us to observe their relationship with space, as well as the manifestation of their spatial thinking.

Keywords: co-creation, model, *SmartCityMaker*, spatial thinking, territory

Introduction

L'espace est un concept complexe à appréhender par les élèves, à la fois constitué de lieux animés et interreliés par des relations (Mérenne-Schoumaker, 2002). Le rapport à l'espace est une expérience subjective (Appell, 2018) qui tient compte de la personne comme étant un être doté d'une cognition incarnée dans un corps ayant un rapport à l'espace physique qui l'entoure. Le rapport à l'espace est ainsi une relation dynamique dans laquelle le sujet et l'espace donnent lieu à une expérience personnelle unique, constituée à la fois d'aspects géographiques factuels que d'aspects socioaffectifs (Laffont & Martouzet, 2018). À un niveau sociétal, le rapport à l'espace peut se comprendre sous la perspective du rapport des citoyens d'une communauté donnée au territoire, comme communauté sociale qui comporte une charge affective, socioculturelle, voire légale (Mérenne-Schoumaker, 2002). Ce rapport peut se développer sous des approches très différentes. Dans une visée d'engagement créatif, nous pouvons envisager un rapport actif au territoire, dans lequel le citoyen ne se contente pas de s'y déplacer pour ses activités personnelles, professionnelles ou académiques, mais plutôt se considère comme un acteur de changement dans cet espace. Ainsi, le développement d'une approche créative sur son territoire est une forme d'agentivité par laquelle le citoyen appréhende l'espace et s'engage dans sa transformation de manière participative (Barthes & Lange, 2018; Romero et al., 2017). Ceci s'aligne avec le contenu du socle commun de connaissances, de compétences et de culture, établi par le ministère de l'Éducation nationale et de la Jeunesse (2015) de la France et considéré comme incontournable pour la scolarité obligatoire de l'élève de six à seize ans. Parmi ces connaissances, l'élève doit apprendre, entre autres, la langue française, les langages mathématiques et informatiques, la conduite de projets collectifs, l'action citoyenne, la résolution de problèmes et la compréhension des sociétés dans le temps et dans l'espace. Dans ce sens, Thémines (2011) affirme que « l'importance donnée au territoire se comprend en regard des finalités actuelles de la géographie scolaire. Il est attendu qu'elle prépare les élèves à l'exercice de leur responsabilité vis-à-vis d'espaces qui s'échelonnent et s'articulent du local au mondial » (p. 77). Ainsi, la présente étude porte sur l'agir de l'élève sur son territoire scolaire grâce à un projet de développement durable intégrant la création d'une maquette et la programmation robotique pour la gestion automatisée des déchets. Ce type de projet exigeant un processus systémique, collaboratif et ayant une perspective opérationnelle axée sur le devenir d'un territoire se situe dans une perspective géoprospective (Emellem et al., 2012; Garbolino & Voiron-Canicio, 2020). Notre étude a pour objectifs, dans un premier temps, d'analyser le rapport des élèves au territoire scolaire à partir des habiletés spatiales mobilisées tout au long du processus de sa représentation sous forme de maquette. En deuxième temps, il est question d'analyser les retours métacognitifs exprimés par les élèves durant la démarche cocréative dans laquelle ils ont été engagés.

Cadre conceptuel

Rapport sociospatial chez l'enfant

Moore (2019) a déjà proposé un modèle sociospatial pour décrire le développement de la relation de l'enfant à son territoire. Il distingue entre trois types d'espace selon leur accessibilité à l'enfant. L'espace habituel de l'enfant se résume souvent à son école, sa maison et ses environs proches. L'espace fréquenté, cependant, est souvent accessible grâce à la compagnie des parents ou d'autres enfants pendant les fins de semaine. L'espace occasionnel, quant à lui, est souvent exploré lors de voyages et de sorties spéciales qui peuvent être organisées par l'école ou la famille. Ce rapport que l'enfant entame avec son territoire à travers ces trois types d'espace lui permet de se situer et de développer un sentiment d'appartenance, condition incontournable pour le futur citoyen qu'il serait (Mérenne-Schoumaker, 2019). La même auteure considère ce rapport crucial étant donné qu'il aide l'enfant à comprendre l'organisation du territoire et les interactions qu'il peut tisser avec son environnement. Ainsi, l'apprentissage de l'espace s'avère important pour le développement personnel et social de l'élève.

Pensée spatiale

La pensée spatiale est définie comme la connaissance conceptuelle, l'habileté à utiliser l'espace, grâce à différents outils de sa représentation et les processus du raisonnement permettant la résolution de problèmes et la prise de décision (Joe et al., 2010; National Research Council, 2006). Cependant, il convient de préciser que l'apprentissage à caractère spatial n'est pas lié exclusivement à la géographie, mais plutôt partagé avec plusieurs disciplines qui contribuent à son développement. La nature épistémologique de la géographie lui permet de créer facilement des liens interdisciplinaires avec d'autres domaines de connaissance. Dans ce sens, Mérenne-Schoumaker (2019) a bien précisé que les échanges de la géographie avec d'autres disciplines ne se limitent pas uniquement aux sciences humaines, car elle établit des liens qui peuvent être étroits avec les sciences, les mathématiques, le français de même que les arts. En effet, les habiletés spatiales sont étroitement liées aux mathématiques à travers la visualisation et la capacité d'imaginer des objets en 2D et 3D (Mix & Cheng, 2012). Ceci est confirmé par Thémines (2011) qui indique que l'exploration des rapports au territoire se fait souvent dans une démarche interdisciplinaire. En effet, plusieurs chercheurs soulignent que la pensée spatiale est fondamentale à l'apprentissage et à la cognition (Hawes et al., 2017; Kell et al., 2013). Selon ces auteurs, la recherche démontre un lien étroit entre la pensée spatiale et la performance à travers les disciplines scolaires constituant le curriculum. Dans le même sens, Newcombe et Shipley (2015) soulignent que :

> Les informations spatiales concernent les formes, les emplacements, les chemins et les relations entre les entités et les référentiels. Ces informations sont représentées dans la cognition humaine et peuvent être transformées mentalement pour aider à manipuler, à construire et à naviguer dans le monde physique, ainsi que pour réussir dans les efforts académiques et intellectuels. (p. 2, traduction libre)

Ces mêmes auteurs insistent sur les caractéristiques intrinsèques de chaque objet spatial telles que sa localisation, son orientation, sa taille et son rapport aux autres entités en fonction de ces mêmes traits. Ils considèrent la transformation mentale d'objets observés sur un plan de 2D en forme de 3D comme une configuration complexe qui fait appel à la visualisation. Cette dernière est définie comme une opération cognitive qui se manifeste dans (dessin, carte, maquette, autre) (Peterson, 1987). Selon cet auteur, on fait appel à la visualisation pour raisonner, contrôler des objets, transformer des images, s'orienter dans l'espace, comprendre les descriptions verbales et créer de nouveaux modèles. C'est ainsi que St-Jean et al. (2022) considèrent la visualisation comme une composante clé du raisonnement spatial. Au-delà de ces aspects, Taylor et Hutton (2013) indiquent que les enfants démontrent plaisir et motivation dans les leçons qui s'articulent autour de l'espace.

Territoire scolaire, objet d'apprentissage cocréatif

L'apprentissage de l'espace aide l'enfant à comprendre les relations qui se tissent autour de lui, qu'elles soient statiques ou dynamiques. Dans ce sens, Liben et Downs (2003) définissent deux types de liens que les élèves peuvent établir entre l'espace réel en 3D et la carte géographique statique basée sur en 2D. Il s'agit des *correspondances relationnelles* qui évoquent la théorie de la sémiotique De Saussure (1986). Ces relations se manifestent dans le lien entre l'information observée réellement dans l'espace appelé *référent* et le symbole par lequel elle est représentée sur la carte nommé *signifié* (qui peut être une notion d'une idée ou un concept auquel le support du signe réfère) et les correspondances géométriques et graphiques qui déterminent le lien entre les caractéristiques spatiales du référent appelé *signifiant* (la carte). Notons bien que le signifié implique un acte d'interprétation par le lecteur (MacEachren, 1995). Ainsi, le passage du plan 2D au plan 3D et vice versa semble une habileté mentale importante de la pensée spatiale. Cette pensée « étant profondément enracinée dans les activités quotidiennes, il est difficile de démêler et apprécier son rôle » (National Research Council, 2006, p. 50, traduction libre). Il s'agit d'un acte constant et omniprésent auquel tous les individus participent tantôt spontanément et tantôt délibérément (Bednarz et al., 2013). Cette affirmation se manifeste selon ces auteurs dans trois contextes : la géographie de nos espaces de vie, les espaces physiques et sociaux et les espaces intellectuels. Ces activités sont reliées à l'expérience de vie spatiale dans laquelle l'enfant fait appel à son sens d'orientation, de distance, de région et de séquence. Or, Romero et Chiardola (2019) soulignent que les enfants, particulièrement ceux habitant l'espace urbain, semblent être limités dans leur rapport au territoire dû autant au contrôle exercé par les parents qu'à la régulation que leur impose l'organisation des villes.

Sur ce, il importe d'exploiter les espaces scolaires, en tant que territoires de vie, étant donné l'effet important qu'ils ont sur l'efficacité des apprentissages acquis et les comportements développés par les apprenants (Mazalto & Paltrinieri, 2013). C'est ainsi que Boix-Tomàs et al. (2015) trouvent importante la relation qui se tisse entre l'éducation et le territoire dans lequel elle se pratique. Dans cette perspective Hardouin (2020) et Taddei (2018) affirment que l'école idéale est celle qui est réellement ancrée dans son environnement sociospatial proche grâce à la coconstruction des projets qui se fondent sur une « intelligence collective ». Cela dit, pour permettre à l'enfant d'établir un rapport plus actif à son territoire proche, il importe que l'école propose des approches pédagogiques développant la cocréation et l'écocitoyenneté. En effet, la pédagogie, ancrée dans le milieu par exemple, permet à l'élève d'établir un lien d'appartenance étroit à son territoire de proximité tout en donnant un sens à ses apprentissages. De plus, construire pour apprendre introduit à une approche enactive et créative de l'apprentissage (Leroy-Viémon, 2008) qui se concrétise dans la création collaborative. L'approche enactive en éducation, inspirée par les travaux de Varela (1997), se concentre sur l'interaction dynamique centre l'apprenant et son environnement. Elle repose sur l'idée que la cognition émerge de l'action et de l'expérience directe, plutôt que d'une simple réception passive de l'information. Ainsi, la présente étude s'inscrit dans le cadre de projets interdisciplinaires *SmartCityMaker*. L'élève est invité à s'engager dans un processus de coconstruction d'une maquette représentant son territoire scolaire et à programmer le circuit d'un robot dans une opération du ramassage des déchets à recycler tout en réfléchissant à des problèmes et des solutions (Wing, 2010). Ledit projet interpelle des habiletés spatiales en géographie, en mathématiques tout en mobilisant les habiletés de communication orale et écrite en français et en utilisant la programmation. L'approche pédagogique, de type enactif, et collaboratif, est orientée sur le développement durable d'un territoire de proximité (quartier scolaire) comme objet d'apprentissage. Le questionnement posé à la suite de ce qui précède est : comment le projet *SmartCityMaker* articulé autour de la création d'une maquette permet-il d'expliciter le rapport que des élèves de 11 ans ont avec leur territoire scolaire?

Méthodologie

L'approche méthodologique de la présente étude est de type recherche-action participative dont les acteurs non seulement participent et contribuent à toutes les étapes de l'étude, mais ils influencent le processus de la recherche en modifiant le déroulement de l'intervention didactique selon les observations directes effectuées au fur et à mesure que le projet avançait. Le recours à la recherche-action se justifie par sa réponse aux besoins sociaux réels puisqu'elle prend place dans le milieu et met à contribution toutes les personnes participantes (Tremblay & Bonnelli, 2007) en plus de créer le changement en vue d'une amélioration (Bradbury et al., 2019). Ainsi, les connaissances produites sont le résultat d'un va-et-vient entre l'action et la réflexion et s'appuient sur les savoirs expérientiels vécus (Racine & Legault, 2001). Dans le cadre de cette étude, l'équipe de recherche-action se compose de deux chercheures et de deux acteurs scolaires, en l'occurrence l'enseignante de la classe, le directeur de l'école, un étudiant en urbanisme, deux parents spécialistes en programmation en plus des élèves participants. La concertation entre les membres de ce collectif a permis le développement d'une confiance mutuelle facilitant le déroulement du projet.

La méthode d'analyse des données est de type mixte, conciliant entre un traitement quantitatif des scores obtenus par les élèves et l'analyse thématique interprétative (Paillé & Mucchielli, 2021) des différentes données collectées (vidéogrammes, questionnaire, feuille du cheminement métacognitif rédigé par les élèves, observation participative des activités, etc.).

Participants

Les participants à la recherche sont 22 élèves âgés de 11 ans de l'école Jean Marie Hyvert à Nice, en France. Cet établissement est une école d'application de l'Inspé de l'académie de Nice. Il s'agit d'une classe de CM2 (5^{e} année primaire) composée de 13 garçons et 9 filles.

Cueillette des données

Les instruments de cueillette de données sont variés afin de collecter le maximum d'informations qui permettent d'analyser et documenter l'étude. En effet, un certain nombre de questions ont été posées aux élèves lors de la lecture du plan cadastre et au moment de la sortie d'observation directe du terrain. Un questionnaire et une feuille du cheminement métacognitif ont été confectionnés par les chercheures et validés par l'enseignante et la direction de l'école afin d'identifier les habiletés et les stratégies spatiales des élèves à la suite de la sortie de terrain. Le questionnaire cherche à décrire et à interpréter les habiletés spatiales que possèdent les élèves alors que la feuille du cheminement métacognitif invite l'élève à être conscientisé de ses apprentissages au fur et à mesure qu'il avance dans l'expérience. Un enregistrement vidéo a été effectué lors des ateliers sur la programmation du robot et pendant la Journée défi où les élèves expérimentent la programmation robotique en la présence de leurs parents. Les chercheures ont effectué l'observation participative lors des différents ateliers. Ainsi, elles ont tenu un journal de bord afin de noter leurs observations directes pendant les différentes étapes de l'étude.

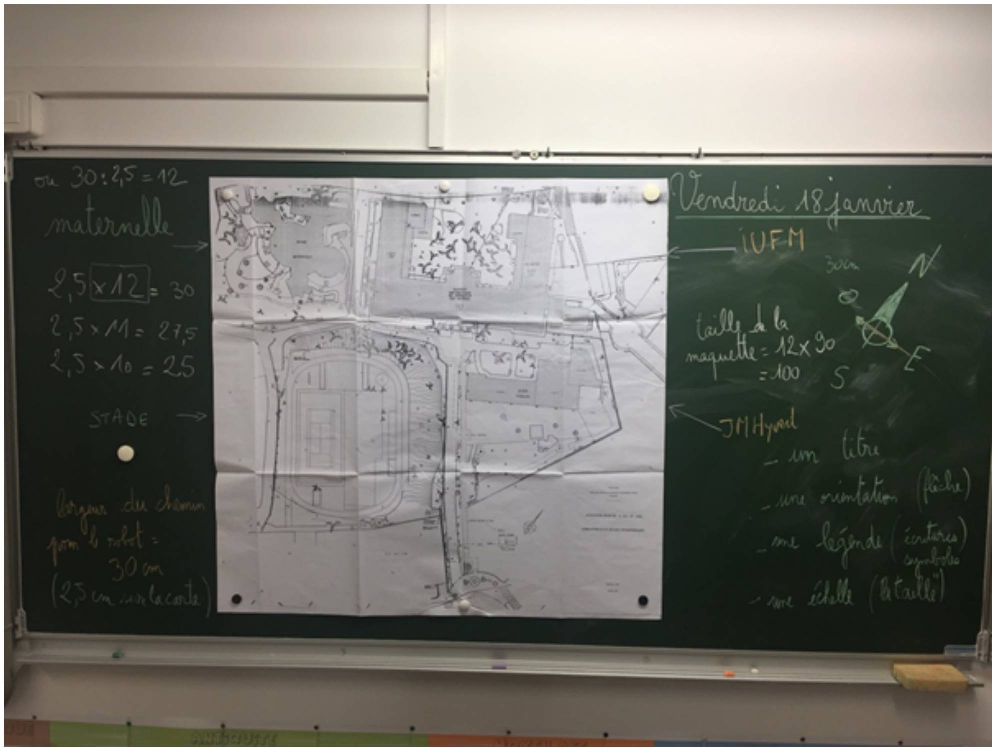
Étapes de l'étude

L'intervention didactique est constituée de cinq étapes dont chacune comporte différents apprentissages. Il s'agit de la lecture du plan cadastre du quartier groupe scolaire (l'école, la garderie, l'Inspé et le terrain de jeux); d'une sortie de terrain pour une observation directe des composantes du territoire à l'étude; d'une deuxième sortie de terrain pour mesurer les hauteurs des bâtiments; une période du traçage des emprises sur la base de la maquette; la programmation du robot pour récupération des déchets triés, pratiquée par tous les participants, et la Journée défi (*Challenge Day*) à laquelle tous les élèves ont participé en présence de leurs parents.

La lecture du plan cadastre de la carte du territoire scolaire a permis aux élèves de décoder les signes et symboles représentés sur la carte (Figure 1). Ainsi, ils avaient à orienter la carte afin de localiser les différentes entités selon les quatre directions cardinales et de mesurer les distances qui les séparent. La lecture d'un plan en 2D vise à les aider à comprendre la notion de l'échelle sur laquelle se base la réduction de l'espace réel à une représentation cartographique (symbolique). Ainsi, plusieurs mesures ont été faites afin de concevoir la représentation de ce même territoire sur une maquette à 3D. Entre la représentation abstraite en 2D et la création d'une représentation à 3D, les élèves avaient besoin d'explorer les lieux par l'observation directe effectuée grâce à une sortie de terrain.

Figure 1

Activité de lecture d'un plan cadastre du quartier groupe scolaire

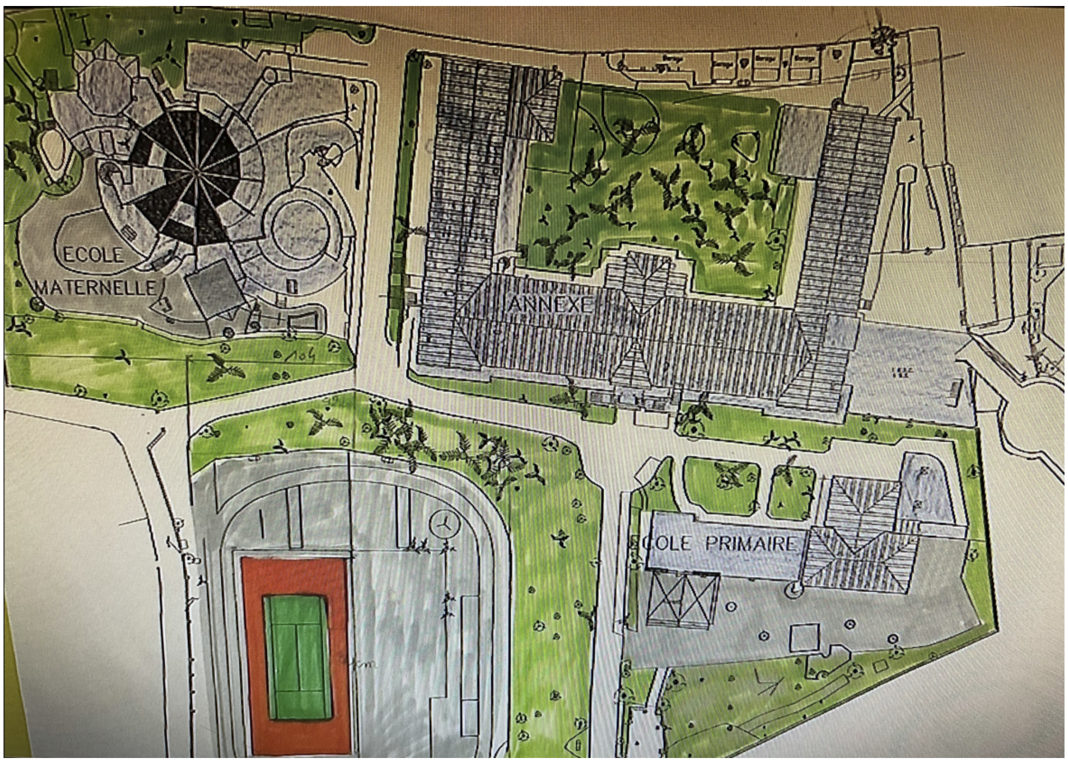


En effet, la sortie de terrain a été organisée pour les élèves participants à l'étude sous l'encadrement de l'une des chercheures, de l'enseignante et du directeur de l'école. L'objectif est de permettre aux élèves d'observer leur territoire de proximité selon d'autres perspectives et angles, de définir des repères, de s'orienter dans l'espace, de situer les édifices les uns par rapport aux autres, d'observer les composantes du quartier (bâtiments, jardins, route, arbres, etc.) et leurs formes (ponctuelle, linéaire, surfacique) et de prendre des mesures de certaines entités. Tout au long de l'exploration du quartier, les élèves avaient à répondre à des questions qui portent essentiellement sur la localisation, l'orientation, la mesure et la perspective. De même, ils avaient la chance de poser des questions. Par collaboration en petits groupes, ils se réfèrent selon leur besoin au plan cadastre qu'ils avaient en main. Ce plan a été peinturé pour indiquer les noms des entités afin de faciliter aux élèves la formation d'une image mentale de leur quartier scolaire (Figure 2).

Après cette sortie, la classe a été divisée en trois grands groupes selon le choix de l'enseignante qui s'est basé sur les forces de chaque élève. Le premier groupe avait effectué un travail de terrain pour prendre les mesures des hauteurs des bâtiments composant l'espace étudié à l'aide d'un télémètre laser, souvent utilisé par les architectes et les paysagistes. Le deuxième groupe s'est occupé de mettre les emprises des entités de l'espace sur la base de la maquette. Ce groupe avait la tâche de tracer l'emprise de chaque bâtiment en respectant l'échelle adoptée avec l'ensemble de la classe. Ainsi, les distances entre les entités spatiales doivent être agrandies d'une manière proportionnelle à l'échelle de la maquette. Le troisième groupe, quant à lui, avait à finaliser la programmation des robots. Bien que chacun des trois groupes avait des tâches différentes, l'ensemble de la classe avait déjà été initié à la notion d'échelle, à la mesure des hauteurs et à la programmation. Une fois les tâches de chaque groupe accomplies, les élèves appartenant à chaque groupe avaient à partager leurs apprentissages avec leurs collègues lors de la confection des bâtiments en 3D et au moment d'expérimenter le circuit du robot.

Figure 2

La coloration des espaces verts et l'identification des entités à représenter



Il convient de noter que les différentes activités réalisées, évoquent un va-et-vient entre le territoire scolaire en tant qu'image mentale (visualisée) et la représentation de ce même territoire sur la carte d'un côté et la concrétisation du lien entre ces deux représentations sur la maquette fabriquée de l'autre côté. Les deux types de représentations, mentale et cartographique, s'enrichissent de l'observation directe pour permettre à l'élève de développer les habiletés spatiales avec lesquelles il fonctionne au quotidien dans sa vie personnelle et sociale. La création de la maquette permet aux élèves participants de faire différents apprentissages qui mettent en valeur leur pensée spatiale, et ce, en ayant recours à la géographie, aux mathématiques, à la technologie et à la littératie. À l'aide du programme EV3, l'élève doit effectuer la simulation collaborative de ramassage et de déchets triés.

Résultats

Localisation et orientation

Les réponses des élèves au questionnaire (Tableau 1) suivant l'activité de la sortie de terrain permettent de brosser un portrait quant aux habiletés spatiales des participants à l'étude. Il convient de rappeler que les six premières questions (1, 2, 3, 4, 5, et 6) cherchent à mesurer les habiletés de localisation relative et absolue, d'orientation et situation. Les scores obtenus montrent que 21 élèves sur 22 sont capables de situer leur école par rapport à l'édifice de l'Inspé et 19 élèves sur 22 localisent adéquatement l'entité qui se trouve le plus au nord (Q2). Cependant, quand il s'agit de la localisation selon les sous-directions cardinales (nord-est, nord-ouest, sud-est, sud-ouest), 21 élèves parmi les 22 n'ont pas pu situer correctement l'entité recherchée.

Tableau 1

Résultats du test sur les habiletés spatiales des participants

Habiletés spatiales		Questions	Réponses appropriées	Réponses à analyser
Localisation absolue/relative	Avant/Après	1	21	1
	Localisation absolue	2	19	3
	À gauche/À droite	3	20	2
		4	20	2
Orientation	Sous-directions cardinales	5	1	21
Situation	Dessus/Dessous/Au même niveau	6	18	4
Inclusion/exclusion	À l'extérieur/Dans/À côté de	7	17	5 (excluent la cour)
Mesure	Longueur approximative	8	-	7 (confusion entre longueur et aire) 15 estimations (3 = 50 m, 12 < 50 m)
Aire	Comparaison visuelle	9	20	2
Stratégies spatiales adoptées pour répondre à la question 9		10	Proportion, visualisation, pratique spatiale, appropriation territoriale	

Deux élèves semblent confondre entre la gauche et la droite et par conséquent ils ne peuvent pas situer correctement leur école par rapport au terrain de jeux (Q3 & Q4) qui se trouve en position presque parallèle à l'école. De même, 4 élèves sur 22 ne sont pas en mesure de situer le niveau du stade par rapport à celui de l'école (Q6). En somme, la majorité des élèves semblent posséder la perception projective de l'espace, mais ils manifestent visiblement une difficulté lorsqu'il s'agit de la pensée euclidienne impliquant les sous-directions cardinales.

Inclusion/exclusion

Pour la question 7, qui mobilise les notions d'inclusion/exclusion, cinq élèves ne considèrent pas la cour de l'école comme un espace inclus à leur école. Cela nous invite à nous interroger sur la représentation mentale que ces élèves se font à propos de leur école. Est-ce que l'école pour ces élèves se limite aux salles de cours, à la cantine, au bureau de la direction, etc.? Est-ce que la cour de l'école est perçue comme un terrain de jeux exclu de l'école?

Longueur et aire

À la question 8 qui cherche à estimer la longueur approximative du stade, les élèves ont fourni des mesures allant de 15 à 300 mètres. Cette divergence invite à tenter d'interpréter la représentation qu'ils se font de la longueur réelle de cette entité de même que leur expérience de jeu et de fréquentation de cet espace. Il importe aussi de comprendre le sens que les élèves donnent au concept de longueur. En effet, sept élèves ont donné deux chiffres dont l'un présente la longueur et l'autre indique la largeur, parmi eux un seul élève a fourni l'aire exacte du stade soit 60 x 20 mètres. Ainsi, ces élèves font une estimation de l'aire du stade et non de sa longueur. Les autres élèves (15) ont fourni une estimation de la longueur dont trois la situent à 50 mètres tandis que 12 élèves suggèrent des mesures inférieures à 50 mètres. Ces réponses indiquent une confusion chez certains élèves (7/22) entre la notion de longueur et celle de l'aire et chez d'autres (12/22), une sous-estimation de la longueur de cette entité.

À la question 9, il est demandé aux élèves de comparer les aires des différentes entités pour en déterminer la plus grande. Seulement 2 élèves sur 22 ne voient pas l'Inspé comme ayant l'aire la plus grande. Sur quels éléments se basent les 20 élèves pour considérer l'aire occupée par l'Inspé? Est-ce qu'ils ont retenu mentalement l'aire représentée sur le plan cadastre ou étaient-ils plutôt influencés par le fait que l'Inspé est le bâtiment le plus imposant en hauteur dans tout le quartier scolaire?

Stratégies spatiales

C'est ainsi que la question 10 s'avère intéressante dans le sens qu'elle cherche à comprendre la réponse des élèves à la question 9. C'est grâce à cette question que l'on peut découvrir certaines stratégies spatiales utilisées par les élèves. En effet, les réponses fournies donnent lieu à quatre catégories d'explication qui informent sur les stratégies spatiales que les participants utilisent. La première catégorie de répondants procède à la comparaison entre l'Inspé et les autres entités spatiales du territoire étudié : « Car l'école est plus petite, le stade pareil et l'Inspé est très grand » (E13); « Je pense que l'Inspé a la plus grande surface » (E22); « J'ai recadré à peu près la taille des bâtiments » (E11). Cette comparaison évoque aussi la notion de proportion des entités les unes par rapport aux autres. La deuxième catégorie d'élèves fait appel à la visualisation pour se représenter mentalement le plan du quartier comme stratégie spatiale : « Je me souviens, sur la carte de la taille de l'Inspé » (E8); « En me rappelant que sur le plan l'Inspé était le plus grand » (E4); « J'ai visualisé le plan » (E9). Dans cette catégorie, un élève parle visiblement de sa capacité de se représenter mentalement l'espace en question selon une perspective azimutale : « On se fait une image d'en haut et on se fait une idée » (E10). La troisième catégorie des participants fait référence à la pratique spatiale qui émane de leur fréquentation quotidienne du territoire scolaire : « Quand je vais à l'école ou au judo, je passe par là et je vois l'Inspé qui est plutôt grande » (E20); « Parce que je suis déjà y allais » (E21). Dans cette même catégorie, un élève fait référence à la sortie de terrain réalisée au début de l'étude : « Car nous sommes allés à l'Inspé et pour moi cela était le plus grand aire » (E14). La quatrième catégorie, quant à elle, se base sur une connaissance de l'environnement scolaire bien ancrée : « Je sais que l'Inspé est la plus grande école ici » (E17); « Je sais où se trouve les choses autour de mon école » (E18). Ce type de réponses divulgue une certaine conviction ancrée chez l'élève qui peut indiquer une certaine appropriation du territoire fréquenté et dénoter un sentiment de contrôle.

Prise de la mesure des hauteurs

Lors de la sortie organisée pour mesurer la hauteur des bâtiments du quartier groupe scolaire, les élèves ont appris à manipuler un télémètre laser. Ils placent l'outil par terre à la base de chaque édifice, en pointant vers le plafond de chaque niveau, ils prennent en note la valeur affichée à l'écran. Les élèves outillés d'un cahier et crayon notaient le nom du bâtiment et les mesures prises. Dans un lieu comme l'Inspé, le plus élevé de tout le quartier étudié, et qui se compose de plusieurs étages, les élèves prenaient la mesure de chaque étage tout en faisant une estimation approximative de l'épaisseur de la dalle qui sépare les étages.

Traçage des emprises des entités sur le plan de la maquette

Le traçage des emprises de chaque bâtiment sur le plan de la maquette s'est fait par plusieurs équipes de 4 à 5 élèves. La décision de diviser la classe en équipes permet à chaque groupe de travailler tout en bénéficiant d'un encadrement étroit de la part de l'enseignante à des moments différents. Cette séquence permet aux élèves de passer d'une petite échelle en 2D à une plus grande échelle, celle de la maquette, en 3D. Pour ce faire, les élèves ont recréé le périmètre du quartier groupe scolaire en multipliant les distances du plan de cadastre par l'échelle adoptée. Chaque équipe contribue au traçage des surfaces à occuper par les bâtiments du quartier. Cette activité a nécessité l'usage d'outils de mesure comme les règles pour mesurer les longueurs, les périmètres et les distances de même que les équerres qui étaient utiles dans le traçage des angles droits. Cette étape a permis aux apprenants d'appliquer la règle liée à la notion d'échelle. Lorsqu'on leur pose la question : « Comment faites-vous pour passer d'une petite échelle sur le plan cadastre à une grande échelle sur la maquette? », ils répondent : « On multiplie, mesurer la distance sur la petite échelle et la multiplier par l'échelle choisie pour l'agrandir. »

Fabrication et peinture des entités en 3D

Une fois que les équipes ont terminé le traçage des emprises des entités, elles avaient à créer les édifices en 3D. Pour ce faire, elles devaient établir une échelle proportionnelle de la hauteur et créer les bâtiments à l'aide de matières recyclables comme des boîtes de carton, du papier et autres objets. Ensuite, les élèves ont procédé à la peinture des entités composant la maquette tout en faisant appel à leur côté esthétique. Il faut noter qu'au moment où les apprenants effectuaient le traçage des emprises des entités et leur création en trois dimensions, ils faisaient appel à leur perception projective de l'espace. Ainsi, ils avaient à déterminer les relations entre les différentes entités quant à leur positionnement (avant/après, devant/derrière, à gauche/à droite, en dessus/en dessous) et de la distance qui les sépare les unes des autres. De même, c'est en cette phase qu'ils ont utilisé les repères identifiés pendant la sortie de terrain pour les considérer au moment de la programmation du parcours du robot afin de ramasser les déchets du quartier. Aussi, ils ont fait appel à la perception euclidienne à l'aide de laquelle ils localisent les composantes du territoire représenté sur la maquette.

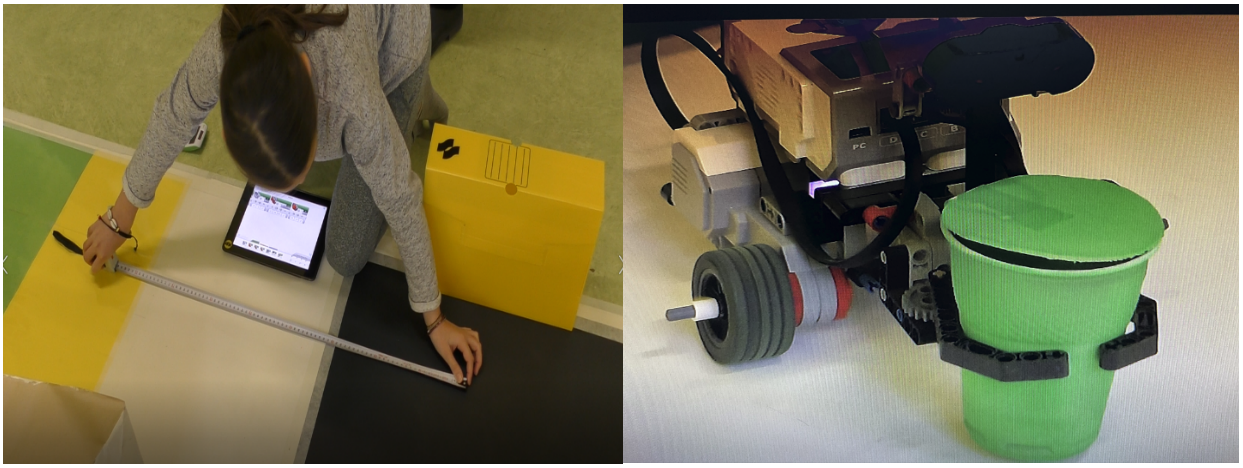
Programmation du circuit à parcourir par le robot (atelier sur la robotique)

Il faut préciser que tous les élèves participants (CM2 = 5^{e} année primaire) à cette étude sont initiés à la programmation dans le cadre du programme d'études du cours de technologies. Cependant, il a été nécessaire aux fins de la présente recherche et pour la participation à la Journée défi (« *Challenge Day* ») qui fait partie de l'intervention didactique planifiée, de pratiquer la programmation afin de permettre au robot de circuler dans le territoire du quartier représenté par la maquette, et de ramasser les différents types de déchets triés.

À la suite de cette séance de programmation, les élèves font un retour métacognitif afin de décrire leurs apprentissages. Certains élèves soulignent l'apprentissage du langage de programmation et autres habiletés : « J'ai appris à me servir de EV3 encore mieux que tout le temps. À me servir de EV3 et des capteurs, rotations, pinces, calcul mental » (E12). D'autres mentionnent les fonctions maîtrisées qui leur permettent de contrôler le mouvement du robot : « Aujourd'hui, j'ai appris à réparer les pinces, à faire reculer le robot et à réparer les capteurs de couleur quand il ne marche plus » (E11). D'autres, quant à eux, insistent sur la résolution de problèmes : « J'ai appris à régler les problèmes de mon programme » (E16); « J'ai révisé comment fonctionne la pince. On s'est trompé, mais on a juste eu à changer le port » (E4). À travers ces commentaires écrits par les élèves, on peut remarquer la nécessité d'effectuer un va-et-vient entre la programmation et la mise en essai du robot afin d'obtenir les mouvements souhaités chez le robot.

Figure 3

Séance de programmation et de mise à l'essai du robot



Journée défi et retours réflexifs des élèves

La Journée défi a été planifiée dans le but de présenter la maquette du quartier scolaire et de permettre aux élèves de mettre en œuvre la programmation dont le but est de guider le robot dans son circuit programmé afin de ramasser les déchets triés en trois couleurs (vert, bleu, jaune).

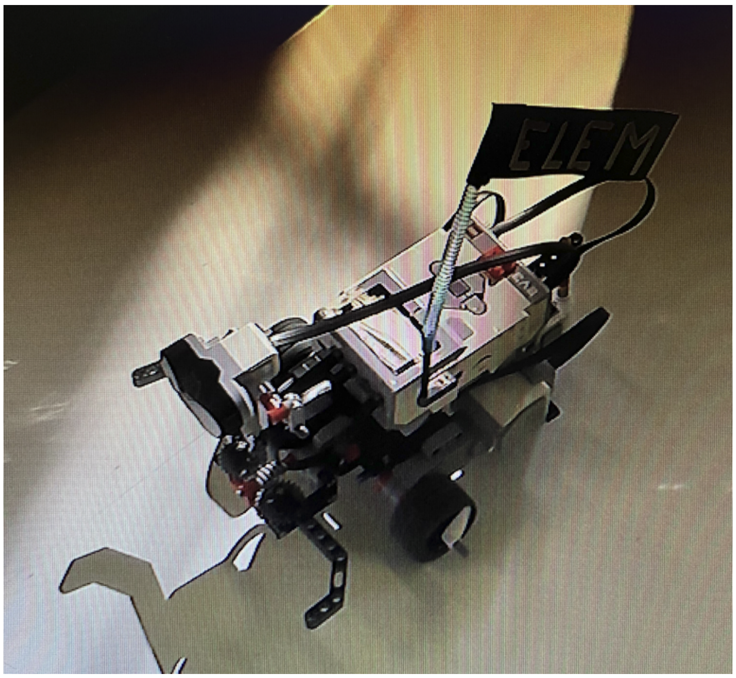
Après avoir accueilli les parents et les élèves, le directeur de l'école présente les consignes aux élèves. Chaque équipe s'occupe d'un robot qui effectuera le ramassage des déchets de l'un des trois bâtiments désignés : l'école maternelle, l'école primaire ou l'Inspé. Il informe les élèves que le défi durera deux heures et les trois équipes seront observées et évaluées par un juge et un arbitre. Les équipes avaient le droit d'aider légèrement le robot à se maintenir sur le bon chemin à parcourir, cependant si le robot dévie complètement du chemin, les élèves doivent revoir la programmation de l'itinéraire établi à partir de leurs tablettes. Une fois que l'équipe termine son essai, les membres de l'équipe doivent déconnecter le robot et le reconnecter pour un deuxième essai.

À la fin de l'activité Journée défi, les élèves étaient invités à faire un retour réflexif sur l'exercice vécu. L'analyse des réponses des élèves s'est basée sur trois catégories, à savoir les problèmes rencontrés, les causes de ces problèmes et les solutions possibles. L'analyse des retours réflexifs, rédigés par les élèves, permet de comprendre leur raisonnement face à ce qu'ils ont vécu.

Tous les élèves ayant participé à l'étude mentionnent le problème de connexion au Bluetooth qu'ils ont rencontré pendant la Journée défi : « Le Bluetooth ne marchait pas » (E7); « Le Bluetooth était souvent en échec de connexion » (E2); « Le Bluetooth ne se connecte pas au robot » (E15). Pour expliquer ce problème, ils s'accordent sur la quantité d'appareils qui étaient connectés dans la salle. Les appareils désignent le nombre des tablettes utilisées par les élèves, mais aussi les téléphones portables des parents qui ont assisté à l'activité : « Il y avait trop d'appareils dans la salle connectés en Bluetooth, cela peut entraîner des problèmes de connexion » (E5); « Beaucoup de téléphones étaient connectés au Bluetooth, le robot avait du mal » (E4). Une élève participante évoque cependant une question logistique qui va au-delà du nombre d'appareils connectés en soulignant qu'il s'agit d'un « problème de réseau » (E16). Pour éviter ce problème, les élèves proposent des solutions organisationnelles comme « Ne pas amener d'appareils connectés au Bluetooth […]. Il faudra à l'avenir les laisser dehors dans une autre pièce » (E5); « Tous les adultes devraient se déconnecter » (E19).

Figure 4

Problème des capteurs de couleurs dû aux rayons du soleil



Un autre problème qui a été observé par plusieurs élèves concerne les capteurs de couleurs qui ne fonctionnaient pas adéquatement selon eux : « Les capteurs couleurs ne marche pas très bien » (E20); « couleur noir et blanc ensemble que le robot confonde avec le bleu » (E11); « Sur notre programme, on a dit au robot de tourner quand il détectait du noir, mais quand c'est le temps qui tourne il avait encore détecté le noir donc il tournait encore et encore » (E9). L'élève E9 suggère « [q]u'on mette des planches de couleurs plus petites ». Pour la même question, l'élève E5 écrit : « Le contour optique avait du mal à détecter les couleurs et en détecter le parcours à suivre. » Ce même élève explique que « [l]e reflet du soleil éclairait le sol d'une manière jaune qui perturbait le robot » et il suggère de « fermer les volets et tapisser le sol de feuilles blanches ». Dans le même sens, une élève indique que « [l]e robot confondait le bleu et le noir […]. Il y avait un scotch blanc sur du noir et ça ressemblait à du bleu » (E19). Elle explique la solution adoptée par son équipe : « On mettait une feuille blanche par-dessus. » Les défis rencontrés par les élèves pendant la Journée défi semblent leur offrir un moment de réflexion sur les possibles solutions et une opportunité d'autorégulation.

Discussion

La création d'une maquette, représentant le quartier scolaire et programmant le circuit d'un robot dans une perspective de développement durable dans le cadre du projet *SmartCityMaker*, semble mettre les apprenants dans un rapport actif à leur territoire scolaire. Allant de son observation à l'aide de cartes en deux dimensions, en passant par son exploration grâce à la visite du terrain jusqu'à sa représentation en trois dimensions. L'apprenant semble s'engager dans une approche enactive et créative de l'apprentissage dans le sens décrit par Leroy-Viémon (2008) et Varela (1997). En effet, il s'agit pour l'élève d'un cheminement de découverte et d'exploration d'un territoire de proximité où il entre en contact avec son environnement grâce à son corps et à une dynamique qui l'amènent vers ce que Leroy-Viémon (2008) appelle « le savoir sensoriel » (p. 93). Cet engagement sociocréatif a permis à l'élève de travailler sur un projet qui s'est constitué grâce à la création collaborative à travers un processus de coconstruction stimulant une intelligence collective (Hardouin, 2020; Taddei, 2018) concernant le territoire scolaire. Ainsi, il s'agit d'une forme d'agentivité par laquelle l'élève citoyen appréhende l'espace et s'engage dans sa transformation de manière participative (Barthes & Lange, 2018).

La création d'une maquette était un prétexte pour engager les élèves dans différents apprentissages signifiants mobilisant les habiletés spatiales en faisant appel à plusieurs disciplines. Ceci rejoint le consensus affirmé par Thémines (2011) et Mérenne-Schoumaker (2019) qui précisent que l'apprentissage du territoire n'est pas exclusif à la géographie. Cette discipline a permis aux élèves de localiser des entités, d'observer leur distribution sur le territoire, de s'orienter dans l'espace, voire de s'approprier un espace dont l'utilisation est éducative. Les mathématiques ont été appliquées pour mesurer les distances entre les entités composant le territoire en sollicitant la visualisation à travers la rotation mentale de la carte cadastrale en 2D à une maquette de 3D (Mix & Cheng, 2012; Newcombe & Shipley, 2015). À cela s'ajoute la manipulation de l'échelle et la mobilisation de différents concepts et formes géométriques tels l'aire, le périmètre, l'angle de 45°, le carré, le rectangle, le triangle, les lignes parallèles, les lignes perpendiculaires, etc.). Pour la programmation, les participants ont fait face, comme c'est le cas pour tout programmeur, à des erreurs (ex., le robot qui ne suit pas son chemin, qui tourne d'une manière répétitive, problème de connexion, etc.) ce qui les a obligés à s'autoréguler en révisant instantanément les codes afin de résoudre les problèmes qui émergeaient. Ceci a engagé les élèves dans la résolution de problèmes faisant appel à la pensée critique et la créativité, comme confirmé par Romero et Chiardola (2019). L'élève E16 l'a bien exprimé en disant : « J'ai appris à régler les problèmes de mon programme. » Cela rejoint ce que Wing (2010) a qualifié de penser en matière de problèmes et solutions. À côté de ces disciplines, l'élève communique oralement avec ses pairs, avec l'enseignante et le directeur en plus de documenter par écrit ses apprentissages grâce à la feuille du cheminement métacognitif. Il importe de ne pas négliger le recours à l'art étant donné que les élèves ont dû créer certains aspects du territoire à l'aide de matières à recycler (ex., création et coloration d'entités miniatures).

Sur le plan méthodologique, l'approche participative et collaborative fut appliquée par les élèves, mais aussi par l'équipe de recherche, incluant l'enseignante et la direction de l'école. Il convient de préciser que deux parents ont contribué aux activités de programmation grâce à leur expertise en informatique. Ainsi, on peut parler d'une capacité importante du travail interdisciplinaire entre les différents acteurs. Bien que le projet *SmartCityMaker* semble prometteur en ce qui a trait aux apprentissages interdisciplinaires réalisés avec les élèves et parmi lesquels la pensée spatiale joue un rôle intégrateur, certaines limites méritent d'être soulignées. En effet, il serait intéressant, grâce à des méthodes cliniques, d'étudier en profondeur comment la pensée spatiale est cognitivement mobilisée chez l'apprenant à travers les différentes activités vécues.

Conclusion

Le projet *SmartCityMaker* entraîne les apprenants dans un processus d'apprentissage de leur quartier scolaire combinant les techniques analogiques et numériques. Ainsi, la création d'une maquette comme démarche d'appréhension du territoire scolaire et de son évolution dans le temps a permis aux élèves de vivre différents apprentissages signifiants (analyse de cartes, observation du terrain, cueillette de données, création d'une maquette, programmation robotique, etc.). Ils se sont pleinement engagés dans un projet collectif, systémique, cocréatif, constitué de plusieurs étapes où ils ont étudié leur environnement scolaire dans une perspective écocitoyenne et géoprospective, démontrant ainsi leur capacité d'agir sur leur propre territoire. Étant donné la richesse des apprentissages interdisciplinaires véhiculés dans le projet *SmartCityMaker* et la mobilisation de différentes compétences transdisciplinaires (collaboration, résolution de problème, communication, créativité, pensée critique, etc.), nous recommandons d'exposer les élèves du primaire et ceux du secondaire à plus de projets axés sur les habiletés spatiales tout en exploitant le territoire scolaire.

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