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Editorial: Technology and Teacher Education in Canada

Éditorial : Technologie et formation des enseignantes et des enseignants au Canada

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Welcome to Volume 50, Issue 4, of *The Canadian Journal of Learning and Technology* (CJLT). This special issue is co-edited by Drs. Mohammed Estaiteyeh, Megan Cotnam-Kappel, and Norman Vaughan on behalf of the *Technology and Teacher Education* (TATE) special interest group.

Technology and Teacher Education is part of the Canadian Association of Teacher Education (CATE), a constituent of the Canadian Society for the Study of Education (CSSE). Its mission is to foster a collaborative network of educational researchers dedicated to exploring the intersections of technology and teacher education in Canada. Aligning with this mission, this special issue showcases Canadian scholar expertise and amplifies the diverse voices of the TATE community.

Inspired by discussions held during our annual TATE conference, where we focused on lessons learned from emergency remote teaching during the COVID-19 pandemic and the rapid technological advancements that teacher education programs are navigating, this issue offers a collection of studies from Canadian researchers working to make teaching and learning with digital technologies more effective, inclusive, and equitable for all Canadians. The research featured in this issue explores the role of digital technologies in and how these innovations are shaping the preparation of teacher candidates for a rapidly evolving digital world. The issue investigates key questions such as:

- How have Canadian teacher education programs adapted their use of educational technologies and digital pedagogies in the post-COVID era?
- In what ways are teacher education programs preparing teacher candidates to navigate today's digital landscape?
- How are teacher education programs adapting to recent advancements in technology, such as artificial intelligence (AI)?
- What success stories can be found in curriculum design, instruction, and assessment that involve technology in teacher education?

We were thrilled by the number of high-quality submissions received for this special issue, reflecting the significant work being done by scholars across Canadian postsecondary institutions. The seven articles selected include a rich variety of research methodologies and reflect TATE's diverse research interests, addressing topics such as online teaching, digital literacy, immersive technologies, maker-centred learning, robotics, and ePortfolios. In line with our commitment to bilingualism, this issue includes contributions in both English and French. TATE continues to extend the call to further grow its bilingual nature and highlight even more francophone voices in its conferences and future special issues.

The first article provides a compelling argument for the need to strengthen teacher education programs in Canada to better prepare teacher candidates for digital classrooms. *Online Teaching During COVID-19: An Analysis of Changing Self-Efficacy Beliefs,* by Julia Forgie, Marguerite Wang, Lisa Dack, and Miranda Schreiber of the University of Toronto, offers a quantitative analysis of Canadian teachers' self-efficacy for teaching online compared to teaching in-person during the COVID-19 pandemic. Results suggest that while the perceived self-efficacy of teachers improved over time, particularly in classroom management and student engagement, it still fell short of the levels of self-efficacy reported for in-person teaching. This study highlights the ongoing challenges educators face in online learning environments and provides valuable insights into how teacher education programs can enhance teacher preparedness for digital instruction.

The second article, *STEM Teacher Candidates' Preparation for Online Teaching: Promoting Technological and Pedagogical Knowledge,* by Mohammed Estaiteyeh, Brock University, and Isha DeCoito and Mariam Takkouch of Western University, puts the aforementioned recommendations into action. This paper focuses on teacher candidates' preparation to teach STEM subjects online within a teacher education program at a Canadian university. Using a mixed methods approach, the authors demonstrate the positive impact of a course intervention on enhancing teacher candidates' technological and pedagogical skills for online teaching. Their research emphasizes the critical need for comprehensive training programs that not only build teacher candidates' technological competencies, but also refine pedagogical methodologies for effective online instruction.

Continuing in the STEM context, the third article explores the integration of emergent technologies, such as educational robotics, into teacher education programs. *Educational Robotics and Preservice Teachers: STEM Problem-Solving Skills and Self-Efficacy to Teach,* by Kamini Jaipal-Jamani, Brock University, employs a mixed methods approach to examine how an educational robotics intervention influences preservice teachers' STEM problem-solving skills and their self-efficacy to teach with educational robotics. This study provides a compelling example of how preservice teachers' self-efficacy to teach with educational robotics was developed within a science education course, and lends unique insights into the problem-solving processes these preservice teacher groups engaged in.

Building on the theme of innovative educational approaches, the fourth article examines implications of maker education for teacher education programs. *The Design and Implementation of Maker Projects in Elementary Schools: A Scoping Review,* by Megan Cotnam-Kappel, Alison Cattani-Nardelli, Sima Neisary, and Patrick R. Labelle of the University of Ottawa, recognizes the growing popularity of maker-centred learning in schools. This French-language article presents a scoping review of maker projects in grades 4–8 classrooms around the globe. The authors outline the stages of maker projects, discuss their effects on both students and teachers, and offer insights into promising practices for designing and integrating maker projects in classrooms. They emphasize the importance of creating maker-centred learning and teaching opportunities within teacher education programs.

The fifth article presents a unique perspective on how Canadian teacher education programs are navigating the evolving digital landscape. *Into the Open: Shared Stories of Open Educational Practices in Teacher Education,* by Helen J. DeWaard of Lakehead University, presents a post-intentional phenomenological study that examines moments, materials, and insights shared by teacher educators. The study highlights the media and digital skills, fluencies, competencies, and literacies that emerge through their open educational practice. DeWaard's research reveals the importance of media and digital literacies in fostering communication, creativity, connections, and criticality within an open educational practice for teacher educators.

On a related note, the sixth article delves into the realm of innovative digital assessments. *ePortfolios: A 360-Degree Approach to Assessment in Teacher Education,* presented by Mpho-Entle Puleng Modise of the University of South Africa and Norman Vaughan of Mount Royal University in Canada, examines how ePortfolios can be leveraged for both assessment and to support student learning in higher education. This self-study examines teacher education programs in a South African and a Canadian context. The findings suggest that students use ePortfolios to integrate self, peer, and teacher/expert feedback, which results in a 360-degree approach to assessment. The study highlights important implications for teacher education research and practice.

The seventh article provides a forward-looking exploration into the evolving role of Artificial Intelligence (AI) in education. *Preparing Educators to Teach and Create With Generative Artificial Intelligence,* by Paula MacDowell, Kristin Moskalyk, Katrina Korchinski, and Dirk Morrison of the University of Saskatchewan, examines how preservice and in-service teachers can be equipped with the knowledge, skills, and mindsets to teach and create with generative AI. Using a self-study method, the authors analyze the curriculum, instruction, and assessment in an upper-level undergraduate course on multimedia design and production. The article offers recommendations for integrating AI literacy meaningfully into teacher education programs, preparing educators for the future of AI-enhanced teaching.

In closing, the guest editors would like to extend their deepest gratitude to CJLT for hosting this special issue and for its commitment to open-access knowledge sharing. Special thanks are due to Carmen Jensen-Tebb and Dr. Martha Cleveland-Innes for their unwavering support and professionalism. We also thank the reviewers for their invaluable contributions to ensuring the rigor of the articles. Congratulations to all the authors! We hope you find the articles as thought-provoking and insightful as we did, and we invite you to enjoy reading this special issue.

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Nous sommes heureux de vous présenter le volume 50, numéro 4, de *La Revue canadienne de l'apprentissage et de la technologie*. Ce numéro spécial est codirigé par les professeur·e·s Mohammed Estaiteyeh, Megan Cotnam-Kappel, et Norman Vaughan, au nom du groupe d'intérêt spécial Technologie et formation des enseignantes et des enseignants.

Ce groupe fait partie de l'Association canadienne pour la formation à l'enseignement (ACFE), qui relève elle-même de la Société canadienne pour l'étude de l'éducation (SCÉÉ). La mission de Technologie et formation des enseignantes et des enseignants est de favoriser un réseau collaboratif de chercheuses et de chercheurs en éducation spécialisés dans l'exploration des liens entre le numérique et la formation enseignante au Canada. Ce numéro spécial s'inscrit dans cette mission en mettant en lumière l'expertise des chercheuses et de chercheurs canadiens et en élargissant la diversité des voix de la communauté du groupe Technologie et formation des enseignantes et des enseignants.

Ce numéro spécial a été inspiré par les discussions tenues lors de notre conférence annuelle, au cours de laquelle nous nous sommes concentrés sur les leçons tirées de l'enseignement à distance mis en œuvre en urgence pendant la pandémie de COVID-19, ainsi que sur les avancées technologiques rapides auxquelles les programmes de formation enseignante doivent s'adapter. Il en résulte un ensemble d'études menées par des équipes de chercheurs de tout le Canada qui œuvrent à rendre l'enseignement et l'apprentissage avec les technologies numériques plus efficaces, inclusifs et équitables pour tous les Canadiens. Les résultats de recherche présentés dans ce numéro examinent le rôle des technologies numériques et la façon dont ces innovations influencent la préparation des futurs enseignants dans un monde numérique en constante évolution. Ce numéro explore des questions clés telles que :

- Comment les programmes canadiens de formation à l'enseignement ont-ils adapté l'utilisation des technologies éducatives et des pédagogies numériques à l'ère post-COVID?
- De quelles manières les programmes de formation à l'enseignement préparent-ils les futures enseignantes et les futurs enseignants à évoluer dans l'univers numérique actuel?
- Comment les programmes de formation à l'enseignement s'adaptent-ils aux récentes avancées technologiques, telles que l'intelligence artificielle (IA)?
- Quels points positifs peut-on observer dans la conception des curriculums, de l'enseignement et de l'évaluation impliquant la technologie dans la formation à l'enseignement?

Nous avons été ravis de recevoir autant d'articles de grande qualité pour ce numéro spécial, ce qui témoigne du travail important que réalisent nos collègues dans les établissements postsecondaires à travers le Canada. Les sept articles sélectionnés reflètent la diversité des intérêts de recherche de la communauté Technologie et formation des enseignantes et des enseignants, couvrant des sujets tels que l'enseignement en ligne, la littératie numérique, les technologies immersives, l'apprentissage centré sur le bricolage (*maker*), la robotique et les portfolios électroniques. Nous avons également veillé à nous assurer d'une diversité de méthodologies de recherche, ainsi que de la présence d'institutions provenant de plusieurs provinces et territoires canadiens. Fidèle à notre engagement en faveur du bilinguisme, ce numéro comprend des contributions en anglais et en français. Toutefois, nous souhaitons valoriser davantage la nature bilingue de notre groupe en invitant de nouvelles voix francophones à se joindre à nos conférences et numéros spéciaux à venir.

Le premier article du présent numéro spécial présente un argument convaincant quant à la nécessité de renforcer les programmes de formation à l'enseignement au Canada afin de mieux préparer les futurs membres du personnel enseignant aux salles de classe numériques. « Enseignement en ligne pendant la COVID-19 : une analyse de l'évolution des perceptions en matière d'auto-efficacité », de Julia Forgie, Marguerite Wang, Lisa Dack, et Miranda Schreiber de l'Université de Toronto, propose une analyse quantitative de l'auto-efficacité des enseignantes et enseignants du Canada dans l'enseignement en ligne comparée à l'enseignement en personne durant la pandémie de COVID-19. Les résultats suggèrent que bien que l'auto-efficacité perçue des enseignantes et enseignants se soit améliorée avec le temps, notamment dans la gestion de classe et l'engagement des élèves, elle reste en deçà des niveaux d'auto-efficacité rapportés pour l'enseignement en présentiel. Cette étude met en lumière les obstacles constants auxquels les personnes enseignantes sont confrontées dans les environnements d'apprentissage en ligne et fournit des perspectives précieuses sur la manière dont les programmes de formation à l'enseignement peuvent améliorer leur préparation à l'enseignement numérique.

Le deuxième article, « Préparer les futurs enseignants en STIM à enseigner en ligne : comment promouvoir les connaissances technologiques et pédagogiques? », de Mohammed Estaiteyeh de la Brock University et Isha DeCoito et Mariam Takkouch de la Western University, met en pratique les recommandations précédemment discutées. Cet article se concentre sur la préparation des futures personnes enseignantes à enseigner les matières des STIM en ligne dans le cadre d'un programme de formation à l'enseignement dans une université canadienne. En utilisant une approche méthodologique mixte, les auteurs démontrent l'effet positif d'une intervention dans le cadre du cours sur les compétences technologiques et pédagogiques des futures personnes enseignantes nécessaires pour l'enseignement en ligne. Leurs travaux soulignent la réelle nécessité pour les programmes de formation complets de développer non seulement les compétences technologiques des futures personnes enseignantes, mais d'affiner également leurs méthodologies pédagogiques pour améliorer l'efficacité de l'enseignement en ligne.

Dans le contexte des STIM, le troisième article explore l'intégration des technologies émergentes, telles que la robotique éducative, dans les programmes de formation à l'enseignement. « Robotique éducative et formation initiale des enseignants : compétences en résolution de problèmes dans les STIM et auto-efficacité pour enseigner », de Kamini Jaipal-Jamani de la Brock University, présente une approche méthodologique mixte pour examiner comment une intervention en robotique éducative influence les compétences des futures personnes enseignantes en résolution de problèmes STIM et leur auto-efficacité à enseigner avec des robots éducatifs. Cette étude offre un exemple convaincant d'amélioration de l'auto-efficacité des futures personnes enseignantes vis-à-vis de la robotique éducative dans le cadre d'un cours de science et fournit des perspectives uniques sur les processus de résolution de problèmes mis en place par ces groupes de futures personnes enseignantes.

Autour des approches éducatives novatrices, le quatrième article examine les implications de l'éducation centrée sur le bricolage (*maker*) pour les programmes de formation à l'enseignement. « Déroulement et retombées de projets bricoleur (*maker*) à l'élémentaire : une revue de la portée », de Megan Cotnam-Kappel, Alison Cattani-Nardelli, Sima Neisary, et Patrick R. Labelle de l'Université d'Ottawa, met en évidence la popularité croissante de l'apprentissage centré sur le bricolage dans les écoles. Cet article en français propose une revue de la portée des projets bricoleur dans les classes de la 4e à la 8e année (secondaire 2) à travers le monde. Les auteurs décrivent les étapes de développement des projets bricoleur, discutent de leurs effets sur les élèves et sur le personnel enseignant, et offrent des perspectives sur les pratiques prometteuses pour la conception et l'intégration de projets bricoleur dans les salles de classe. L'équipe souligne aussi l'importance de créer des occasions d'apprentissage et d'enseignement centrées sur le bricolage physique, numérique et hybride dans les programmes de formation à l'enseignement.

Le cinquième article présente une perspective unique sur la manière dont les programmes de formation à l'enseignement au Canada s'adaptent au paysage numérique en constante évolution. « À découvert : des histoires partagées de pratiques éducatives libres dans la formation des enseignants », de Helen J. DeWaard de la Lakehead University, propose une étude phénoménologique post-intentionnelle qui examine les moments, les matériaux et les perspectives partagés par les formateurs d'enseignants. L'étude met en lumière les compétences, les aptitudes, la maîtrise et les littératies médiatiques et numériques qui émergent dans leur pratique éducative ouverte. Le travail de DeWaard révèle l'importance des littératies médiatiques et numériques pour favoriser la communication, la créativité, les échanges et la pensée critique au sein des pratiques éducatives ouvertes pour les formateurs d'enseignants.

Dans la même veine, le sixième article explore le domaine des évaluations numériques innovantes. « Les portfolios numériques : une approche à 360 degrés de l'évaluation dans la formation des enseignants », de Mpho-Entle Puleng Modise de l'Université d'Afrique du Sud et Norman Vaughan de l'Université Mount Royal, examine dans quelle mesure les portfolios électroniques peuvent être utilisés à la fois pour l'évaluation et le soutien des apprentissages des étudiants dans l'enseignement supérieur. Cette étude de cas compare les programmes de formation à l'enseignement dans un contexte sud-africain et canadien. Les résultats suggèrent que les étudiantes et étudiants utilisent les portfolios électroniques pour intégrer les retours de leurs pairs, de leurs enseignants et d'experts, ce qui aboutit à une approche d'évaluation à 360 degrés. L'étude met en avant des implications importantes pour la recherche et la pratique relativement à la formation à l'enseignement.

Le septième article offre une exploration tournée vers l'avenir du rôle de l'intelligence artificielle (IA) dans l'éducation. « Préparer les éducateurs à enseigner et à créer avec l'intelligence artificielle générative », de Paula MacDowell, Kristin Moskalyk, Katrina Korchinski, et Dirk Morrison de l'Université de la Saskatchewan, examine comment les enseignants en formation initiale et continue peuvent acquérir des connaissances, des compétences et l'état d'esprit nécessaires pour enseigner et créer avec l'intelligence artificielle générative. À partir d'une étude de cas, les auteurs analysent le curriculum, l'enseignement et l'évaluation dans un cours de niveau avancé en conception et production multimédia. L'article propose des recommandations pour intégrer de manière significative la littératie en IA dans les programmes de formation à l'enseignement, ce qui préparerait ainsi les éducateurs pour l'avenir de l'enseignement assisté par l'IA.

En conclusion, les codirecteurs de ce numéro spécial tiennent à exprimer leur plus profonde gratitude à *La Revue canadienne de l'apprentissage et de la technologie* pour avoir accueilli ce numéro spécial et pour son engagement envers le partage des connaissances en libre accès. Des remerciements particuliers sont adressés à Carmen Jensen-Tebb et à la professeure Martha Cleveland-Innes pour leur soutien indéfectible et leur professionnalisme. Nous tenons également à remercier les évaluatrices et les évaluateurs pour leurs précieuses contributions, qui ont assuré la rigueur scientifique des articles. Félicitations à tous les auteurs! Nous espérons que vous trouverez les articles aussi stimulants et enrichissants que nous, et nous vous souhaitons beaucoup de plaisir à lire ce numéro spécial.

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Online Teaching During COVID-19: An Analysis of Changing Self-Efficacy Beliefs

Enseignement en ligne pendant la COVID-19 : une analyse de l'évolution des perceptions en matière d'auto-efficacité

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Abstract

This quantitative study investigated teachers' self-efficacy for teaching online compared to teaching in-person during the COVID-19 pandemic. Teacher self-efficacy is a significant predictor of both teacher practice and student outcomes. During the pandemic, teachers were forced to suddenly shift their teaching online and as a result, many new challenges were faced. Teachers from three teaching contexts (public, private, and virtual public schools) in Ontario, Canada completed the Ohio State Teacher Efficacy Scale (OSTES) and questionnaires measuring online teaching experience and training in May–June 2020 (phase 1) and again one year later, in May–June 2021 (phase 2). Results indicated that while the perceived self-efficacy of teachers improved over the course of the study, specifically in classroom management and student engagement, their perceived self-efficacy did not reach the levels reported for self-efficacy for in-person teaching, highlighting the persisting limitations educators experience in online learning environments. Additionally, efficacy for instructional strategies had not significantly increased by phase 2, indicating a particular need of targeted instruction for future teacher education programs. These results offer insights into the kind of experience and tools teacher education programs can extend to enhance teacher preparedness, and the conditions that best encourage improvements in self-efficacy for in-service teachers.

Keywords: COVID-19, online teaching, professional development, teaching efficacy

Résumé

Cette étude quantitative s'est intéressée à l'auto-efficacité des enseignants relativement à l'enseignement en ligne par rapport à l'enseignement en personne pendant la pandémie de COVID-19. L'auto-efficacité est un facteur déterminant de la pratique de l'enseignant et des résultats observés chez les élèves. Pendant la pandémie, les enseignants ont été contraints de passer subitement à l'enseignement en ligne et ont par conséquent dû surmonter de nombreux nouveaux obstacles. Des enseignants appartenant à trois environnements d'enseignement (écoles publiques, privées et publiques virtuelles) en Ontario, au Canada, ont répondu au questionnaire *Ohio State Teacher Efficacy Scale* (OSTES) ainsi qu'à d'autres questionnaires permettant d'évaluer l'expérience et la formation en matière d'enseignement en ligne en mai-juin 2020 (phase 1), puis un an plus tard, en mai-juin 2021 (phase 2). Les résultats indiquent que si l'auto-efficacité perçue des enseignants s'est améliorée au cours de l'étude, notamment en ce qui concerne la gestion de la classe et la participation des élèves, elle n'a pas atteint les niveaux constatés dans le cas de l'enseignement en personne. Ces données mettent en évidence le fait que les éducateurs sont toujours confrontés à des difficultés dans le cadre de l'enseignement en ligne. Par ailleurs, l'efficacité des stratégies d'enseignement n'avait pas augmenté de manière significative lors de la phase 2, ce qui laisse à penser que les programmes de formation des enseignants devront mettre en place un apprentissage à cet effet. Ces résultats donnent un aperçu du type d'expérience et d'outils que les programmes de formation des enseignants pourraient offrir pour améliorer la préparation des enseignants, et des conditions qui favorisent le plus l'amélioration de l'auto-efficacité des enseignants en exercice.

Mots-clés : COVID-19, développement professionnel, efficacité de l'enseignement, enseignement en ligne

Introduction

Teacher efficacy refers to teachers' beliefs about their ability to help students learn or to bring about desired outcomes for students (Bandura, 1977). Previous research has established teacher efficacy as a significant predictor of both teacher practice and student outcomes. High levels of teaching efficacy are associated with positive effects on student educational experience and performance (Allinder, 1994; Tschannen-Moren & Woolfolk Hoy, 2001). For instance, teachers with higher levels of self-efficacy are more willing to implement diverse teaching strategies to support student success (Allinder, 1994; Carleton et al., 2008; Guskey, 1988). While existing literature has documented the inherent challenges and promise of online education in K–12 settings, relatively little scholarship has compared how teachers experience online learning with how they perceive in-person learning, especially in the context of the sudden, forced transition to emergency remote teaching (ERT) necessitated by the pandemic. For instance, one of the potential discrepancies between online and in-person teaching during COVID-19 identified by Teo et al. (2021) was the use of technology to emulate in-person teaching or re-create the in-person classroom experience. Tools and strategies used in in-person teaching are not entirely transferable online and trying to emulate teaching in-person in a virtual classroom can affect teachers' perceptions of their ability to engage students and plan lessons. Furthermore, the unprecedented nature of the transition to online teaching in a time marked by great uncertainty may have heightened these effects among teachers who have not previously taught in this modality. Many teachers were suddenly required to learn how to navigate a new virtual classroom and select resources with limited support from school boards. This paper examines whether Ontario teachers' levels of self-efficacy at the start of the transition into online teaching improved as they gained more experience and how they differ from their perceptions of self-efficacy teaching in-person. The results of this inquiry offer meaningful data for teacher education programs seeking to prepare preservice educators for delivering curricula online and highlight potential gaps and areas of focus in post-COVID-19 teacher education programs in Canada.

Literature Review

Emergency Remote Teaching

In the spring of 2020, the modality of in-person teaching suddenly shifted online due to increasing pandemic-related public health concerns. For the remainder of the school year, ERT was enacted (Schlesselman, 2020). Emergency remote teaching is defined as "a temporary shift of instructional delivery to an alternate delivery mode due to crisis circumstances" (Hodges et al., 2020, para. 13). The adoption of online learning in a situation of emergency represents not only a need, but has also stimulated experts, policymakers, teachers, and learners to search for new online pedagogies and instructional methods (Ferri et al., 2020). Ferri and colleagues (2020) concluded that ERT has given a significant boost to online learning, opening new opportunities and reflections for the educational system. Despite ERT allowing students to continue their studies amid a global pandemic, there is also evidence that it produced significant loss in educational achievement (Eyles et al., 2020). Additionally, ERT makes it harder to support students with special needs in their learning activities (Ferri et al., 2020).

Online learning is a form of distance education that is intentional and carefully designed to create a meaningful virtual learning experience. Teachers prepare well in advance for their online classes and use pedagogical approaches for assessment, engagement, and instruction that is specific to the virtual learning environment (Pryor et al., 2020; Schultz & De Mers, 2020). In contrast, the shift to ERT is temporary due to crisis circumstances (Hodges et al., 2020), where teachers and instructors work under stressful circumstances with little to no knowledge on when the crisis will end (Affouneh et al., 2020). Thus, in ERT, the goal is not to re-create a vigorous educational ecosystem but to provide temporary access to instruction in a way that is reliable and easily accessible during a time of crisis—such as the spring 2020 lockdown.

Significance of Teacher Efficacy

Research on teacher efficacy illustrates the relationship between teacher practice and student outcomes. Teachers with a higher sense of efficacy are more likely to try different instructional approaches until students are successful (Allinder, 1994); they tend to invest more effort in their teaching, be more enthusiastic, and persist more in the face of challenges and with students who are struggling (Tschannen-Moran & Woolfolk Hoy, 2001). Teaching efficacy also relates to student outcomes such as student achievement (Gibson & Dembo, 1984; Muijs & Reynolds, 2002), motivation (Ashton & Webb, 1986), and students' own sense of efficacy (Tschannen-Moran & Woolfolk Hoy, 2001). Additionally, there is evidence that teachers with higher levels of efficacy are more positive about implementing instructional innovation and trying new teaching methods and technologies (Allinder, 1994; Carleton et al., 2008; Guskey, 1988). In contrast, teachers with lower self-efficacy are more likely to persist with ineffective instruction (Soodak & Podell, 1993) or to use controlling instructional management methods, which can lead to stressful student behaviour and the teacher's reduced sense of personal accomplishment (Martin et al., 2012).

Research on Online Teaching Efficacy

Studies exploring teaching efficacy are mainly centred around in-person contexts, and research in teaching efficacy in online education is still relatively new, particularly in a Canadian K–12 context. There is some research on teaching efficacy in the context of online instruction, though much of it examines postsecondary instructors. For instance, research shows that postsecondary instructors' self-efficacy generally increases with experience teaching online (Gosselin et al., 2016; Horvitz et al., 2015; Northcote et al., 2015). Gosselin et al. (2016) used online teachers' self-efficacy to develop a professional development program and found that teachers' prior experience had an impact on their self-efficacy for teaching online. Similarly, Horvitz et al. (2015) examined postsecondary instructors' self-efficacy for online teaching and found that those with more experience teaching online had higher levels of self-efficacy in online teaching. Furthermore, self-efficacy in nurse educators correlates with number of experiences teaching online and is especially higher for those who have had supportive preparatory experiences (Robinia & Anderson, 2010).

There is also some research representing elementary and high school teachers; despite a negative relationship between years of teaching experience and self-efficacy in the four areas of Technological Pedagogical Content Knowledge-Web, experiences of web-related pedagogical practice correlated positively with self-efficacy in these areas (Lee & Tsai, 2010). Regarding teachers' technology use in classrooms, Chen (2010) found that self-efficacy for teaching with technology had the most significant effect on using technology in the classroom. This finding implies that teachers who have lower levels of self-efficacy in technology may be less likely to try new technologies and use them to support their teaching. Furthermore, this notion is supported with studies indicating that successful past experiences and encounters with technology in teaching increased teachers' self-efficacy for using technology in their classrooms (Moore-Hayes, 2011; Wang et al., 2004).

Zee and Koomen (2016) concluded that a major challenge to teacher self-efficacy research is examining the complex and comprehensive nature of the teacher self-efficacy construct. This is because a large proportion of empirical studies failed to use more complex, multidimensional measures (Klassen et al., 2011; Zee & Koomen, 2016). The current study attempts to explore the complex and nuanced nature of teaching efficacy by assessing teaching efficacy across three dimensions: instructional strategies, classroom management, and student engagement.

Comparing In-Person to Online Teacher Efficacy

While there is a fair amount of research on efficacy for in-person teaching and a small amount on efficacy for online teaching, little research compares teacher efficacy for in-person teaching to online instruction. Zagorski (2011) made this comparison by obtaining responses from first- and second-grade online teachers who had taught in both an in-person and online modality. A modified Ohio State Teacher Efficacy Scale (OSTES) was administered to the teachers, and results uncovered that teachers felt more isolated teaching online than in-person and that these feelings of isolation were associated with lower self-efficacy than teaching in-person (Zagorski, 2011). However, it is unclear how Zagorski's study measured efficacy for in-person teaching and whether it was directly comparable to efficacy for online teaching. Dreon et al. (2018) found focus group participants' reported classroom management was perceived to be easier for online instruction than for face-to-face instruction. However, this study only measured efficacy for online teaching, not for in-person teaching. Lin and Zheng (2015) found that teachers of a Chinese language course considered classroom management to be easier online than in person, possibly in part due to students' being more motivated to learn a foreign language online. Importantly, none of these studies were conducted with teachers who were suddenly required to move their teaching online, with little time for preparation or planning, demonstrating a further need for more research.

Online Teacher Efficacy During COVID-19

Online teaching during COVID-19, also referred to in the literature as ERT, presented a unique challenge due to the emergency context and the speed and suddenness of the transition into an online environment. Consequently, both teachers and school boards had little time to prepare for the new modality and provide adequate support, which may have impacted teacher efficacy. There are few studies that have investigated teachers' online efficacy during COVID-19. In the context of COVID-19 ERT, it was found that teachers' general self-efficacy decreased (Cataudella et al., 2021; Pressley & Ha, 2021; Yenen & Çarkit, 2021). Similarly, Ma and colleagues (2021) found that teachers reported lower self-efficacy at the beginning of online teaching. However, online teaching efficacy levels increased after the COVID-19 pandemic concluded (Baroudi & Shaya, 2022; Ma et al., 2021).

A significant predictor of teacher self-efficacy during remote instruction during COVID-19 relates to the remote learning modalities schools were employing. Teachers working at schools that used online instruction alone reported the highest levels of self-efficacy in the Teachers' Sense of Efficacy Scale (TSES), while teachers who taught in schools that supported online instruction with instructional packets reported the second highest levels of overall TSES (Marshall et al., 2022). Finally, teachers that only delivered instruction through hard-copy materials provided to students reported the lowest levels of self-efficacy (Marshall et al., 2022). Thus, it is clear that support for online teaching affects teaching self-efficacy.

Dolighan and Owen (2021) looked at self-efficacy perceptions for online teaching in the context of the early stages of COVID-19. In this study, secondary teachers in southern Ontario completed a modified version of the Michigan Nurse Educators Sense of Efficacy for Online Teaching with subscales for student engagement, classroom management, online instruction, and use of computers. Results demonstrated that neither years of experience teaching in-person nor number of online teaching experiences correlates with efficacy for online teaching. Furthermore, DeCoito and Estaiteyeh (2022) found that experienced teachers faced challenges in online teaching due to lack of readiness and lack of required technological skills, thereby impacting their self-efficacy.

These results differ from previous work which showed that online teaching experience was positively correlated with self-efficacy (Gosselin et al., 2016; Horvitz et al., 2015; Northcote et al., 2015), pointing to the emergency context of COVID-19 as a possible explanation for these differences, and thus warranting further exploration and comparison of teachers' online versus in-person teaching efficacy during COVID-19. Research by Bandura (1994) also found that highly emotional situations marked by stress can diminish self-efficacy. Furthermore, Teo et al. (2021) described some of the potential discrepancies between online and in-person teaching during COVID-19; one being the use of technology to emulate the in-person classroom experience even if in-person teaching tools may not be entirely transferable online. This mismatch may be due to inexperience implementing online pedagogies as well as time constraints in training teachers by school administrations caused by the sudden shift to online learning and thus, could also have an impact on self-efficacy. Additionally, individuals in the field of K–12 distance, online, and blended learning mentioned that teachers need to explore ways to reach students at a distance without relying on the Internet. Interviewees also mentioned the importance of using video, synchronous and asynchronous, to interact with students (Barbour, 2020). Similarly, Cardullo et al. (2021) concluded that K–12 teachers faced challenges with Internet connection, student engagement, and lack of interaction which reduced their self-efficacy. Thus, low-tech alternatives to online learning and an emphasis on the use of tools such as video should be considered to enhance K–12 online teaching.

Research Questions

A comparative analysis was performed to examine the differences between Ontario K–12 teachers' self-reported efficacy before (in-person teaching), immediately following (phase 1), and one year after (phase 2) the transition to online education prompted by the COVID-19 pandemic. Further analysis examining implications in teaching efficacy based on teaching context (public, private, virtual public schools) was also explored. To capture these unique concerns, the following research questions were investigated:

1. What are teachers' levels of perceived self-efficacy for classroom management, student engagement, and instructional strategies (for in-person, as well as for online teaching)? Are there any differences in the aforementioned areas of self-efficacy for online teaching based on time and experience (differences between phase 1 and phase 2)?
2. What are teachers' instructional practices in relation to teaching in an online format? This question was related to the amount of time teachers were spending planning and implementing different formats of online instruction.
3. Are there any differences in self-efficacy across virtual, public, and private school teachers? Can differences in terms of online learning experience and training across these three groups reveal any potential implications for future teacher education programs?

Methods

Research Design

The following quantitative study employed online surveys and rating scales to measure teaching efficacy in both the in-person and online teaching context. Private school teachers were recruited from private and independent schools, and public and virtual school teachers were recruited using social media and were members of teaching-focused groups on Facebook. Online surveys and recruitment were determined to be the most effective way of collecting data due to the social distancing measures enacted in the province at that time as well as the urgent nature of the study. Quantitative surveys were necessary to examine gaps in teachers' efficacy in online teaching throughout the duration of the pandemic and how training and time may have influenced this process.

Participants

Teachers from three teaching contexts (public, independent/private, and virtual public school teachers) in Ontario, Canada were recruited to participate in two phases of the study. In this study, *virtual teachers* refers to public school teachers in Ontario who were assigned to virtual schools during the COVID-19 pandemic and taught online for the entirety of the pandemic, offering a virtual option for students regardless of lockdown status. These teachers therefore presumably accrued more experience in online teaching than other teachers, potentially offering insights into the central research interests of this study. No participants reported having previous experience teaching online prior to the start of the COVID-19 pandemic.

Participants were recruited from two main pools: (a) private and independent schools that had previously given administrative approval for this study; and (b) members of teaching-focused groups (e.g., Ontario Kindergarten Teachers, Ontario Grade 3 Teachers, and Ontario Grade 12 English Teachers) on Facebook, with the group's administrative approval. As virtual teachers were from public schools, they were also recruited from the Facebook groups. All teachers surveyed were in good standing with the Ontario College of Teachers. In phase 1, which took place during the early stages of the pandemic in 2020, 372 K–12 teachers participated. Phase 2, which took place early in 2021, invited the same participants to complete the second phase of the study, with 104 teachers returning. Table 1 depicts the demographic characteristics of participants across the three teaching contexts in phase 1.

Table 1

Demographic Characteristics of Participants Across Teaching Contexts in Phase 1

Baseline characteristic	Public school teachers		Private school teachers		Virtual school teachers	
	n = 141	%	n = 101	%	n = 130	%
Gender						
Female	131	92.91	85	84.16	120	92.31
Male	9	6.38	16	15.84	9	6.92
Nonbinary	1	0.71	0	0	1	0.77
Missing	0	0	0	0	0	0
Age						
20–29	22	15.60	18	17.82	29	22.31
30–39	61	43.26	33	32.67	47	36.15
40–49	49	34.75	25	24.75	41	31.54
50–59	9	6.38	17	16.83	12	9.23

Baseline characteristic	Public school teachers		Private school teachers		Virtual school teachers	
	n = 141	%	*n* = 101	%	*n* = 130	%
60–69	0	0	8	7.92	1	0.77
Missing	0	0	0	0	0	0
Languages spoken						
Only English	89	63.12	61	60.40	90	69.23
English & other language(s)	52	36.88	40	39.60	36	27.69
Missing	0	0	0	0	4	3.08
Education						
Undergraduate	20	14.18	14	13.86	28	21.54
Graduate	121	85.82	87	86.14	101	77.69
Missing	0	0	0	0	1	0.77
Tech-related AQs						
None	116	82.27	88	87.13	107	82.31
Librarian AQ	10	7.09	3	7.09	10	7.69
Technology AQ	15	10.64	10	10.64	13	10
Missing	0	0	0	0	0	0
Grades Taught						
Kindergarten	27	19.15	16	15.84	16	12.31
Grade 1	25	81.56	9	8.91	17	13.07
Grade 2	24	17.03	10	9.90	15	11.54
Grade 3	22	15.60	14	13.86	18	13.85
Grade 4	27	19.15	8	7.92	15	11.54
Grade 5	27	19.15	13	12.87	31	23.85
Grade 6	29	20.57	10	9.90	27	20.77
Grade 7	30	21.28	18	17.82	16	12.31
Grade 8	25	17.73	19	18.81	21	16.15
Grade 9	20	14.18	36	35.64	4	3.08
Grade 10	21	14.89	42	41.58	2	1.54
Grade 11	21	14.89	47	46.54	3	2.31
Grade 12	21	14.89	41	40.59	3	2.31

Note. AQ = additional qualification.

Procedure

This study took place in two phases; during phase 1 in 2020, early in their transition to online learning, 372 teachers completed the online OSTES twice; once while reflecting on their online teaching practices and once while reflecting on their in-person teaching practices, prior to the pandemic. A demographic and background survey was conducted alongside the scales. During phase 2 in early 2021, the teachers completed the online OSTES once more, this time considering their online teaching practices only. The demographic survey was administered again at this time to capture a sense of change in teaching practices and placement over time. Phase 2 surveyed 104 returning teachers. By phase 2, all teachers had taught online for, at minimum, a substantial portion of the 2020–2021 school year and thus had gained additional online teaching experience.

Materials

Measure of Demographic Background and Training for Online Teaching

Teachers completed an online survey where they provided demographic information and reported the total number of hours spent engaging in both technical and pedagogical training for online learning. For this research study, *technical training* refers to training related to the use of technology and *pedagogical training* refers to training that targets the pedagogy of teaching online. Additionally, participants reported the number of hours in which they engaged in real-time synchronous online instruction on applications such as Zoom and asynchronous online instruction which assigned tasks to be completed independently.

The Ohio State Teacher Efficacy Scale

Participants' teaching efficacy was measured using the OSTES, a 24-item self-assessment aimed at evaluating teachers' perceptions of their own ability to engage in various instructional activities (Tschannen-Moran & Woolfolk Hoy, 2001). For each item, participants rated the extent to which they could engage in a particular teaching-related activity on a 9-point scale. The scale is divided into three sub-scales: efficacy for instructional strategies, efficacy for classroom management, and efficacy for student engagement, which have internal reliability of .91, .90, and .87, respectively. Table 2 depicts some sample items for each of the subscales.

Table 2

Sample Items From the Ohio State Teacher Efficacy Subscales

Subscale	Example	Sample items
Efficacy for instructional strategies	Instruction and explanation of curriculum content; gauging student understanding, and assessment practices.	Item 7: How well can you respond to difficult questions from your students? Item 20: To what extent can you provide an alternative explanation or example when students are confused?

Subscale	Example	Sample items
Efficacy for classroom management	Setting expectations, managing challenging behaviours, and establishing rules and routines.	Item 5: To what extent can you make your expectations clear about student behaviour? Item 15: How much can you do to calm a student who is disruptive or noisy?
Efficacy for student engagement	Ability and strategies to keep students motivated and interested, helping students value learning.	Item 1: How much can you do to get through to the most difficult students? Item 4: How much can you do to help your students value learning?

Data Analysis

Quantitative data analysis was performed using SPSS (Version 28). Firstly, to assess changes in teachers' self-efficacy beliefs from phase 1 to phase 2, paired *t*-tests were conducted for each of the OSTES subscales. Secondly, paired *t*-tests were conducted to analyze differences in teachers' pedagogical and technical training from phase 1 to phase 2. Analysis of variance (ANOVA) and post hoc tests were also conducted to examine differences in teaching efficacy, online teaching experience, and training across the three teaching groups (public, private, virtual) for in-person and online (phase 1 and phase 2) teaching contexts. To determine the internal consistency of the OSTES, a reliability analysis was conducted using Cronbach's alpha. Table 3 presents the results of the reliability analysis conducted on the three iterations (in-person*,* phase 1, and phase 2) of the OSTES survey employed in the present study. As depicted in Table 3, the reliability of the three scales was above 0.80 for all three timepoints of the OSTES survey, which reflects a good level of internal consistency.

Table 3

Internal Consistency Reliability of Scales

Composite	Cronbach's alpha		
	Phase 1	Phase 2	In-person
Instructional strategies	0.858	0.875	0.933
Classroom management	0.909	0.990	0.920
Student engagement	0.859	0.863	0.852

Results

Paired *t*-tests were conducted for each subscale to compare teachers' efficacy at phase 1 and phase 2 with in-person teaching efficacy. In phase 1, teachers' self-efficacy for instructional strategies, classroom management, and student engagement were all significantly greater for in-person teaching than online (Table 4), suggesting that teachers had lower self-efficacy beliefs when first moving to an online teaching modality. The effect size, Cohen's *d*, was above 0.80 for all scales, indicating a large effect.

Table 4

Teacher Self-Efficacy Scores In-Person Versus Phase 1

Scale	In-person		Phase 1 online		*t*	*df*	*d*
	M	*SD*	*M*	*SD*			
Instructional strategies*	7.89	1.07	6.23	1.36	1.69	323	1.15
Classroom management*	7.56	1.12	6.31	1.71	-10.16	285	0.87
Student engagement*	7.45	0.98	5.66	1.36	-20.29	326	1.44

* $p < .001$.

Similarly, in phase 2, teachers' self-efficacy for instructional strategies, classroom management, and student engagement were significantly greater for in-person teaching than online (Table 5). The effect size, Cohen's *d*, was above 0.50 for all scales, indicating a moderate to large effect.

Table 5

Teacher Self-Efficacy Scores In-Person Versus Phase 2

Scale	In-person		Phase 2 online		*t*	*df*	*d*
	M	*SD*	*M*	*SD*			
Instructional strategies*	8.01	1.12	6.43	1.39	8.60	91	0.90
Classroom management*	7.91	1.01	6.70	1.51	6.07	89	0.64
Student engagement*	7.62	0.86	5.40	1.41	20.67	205	1.12

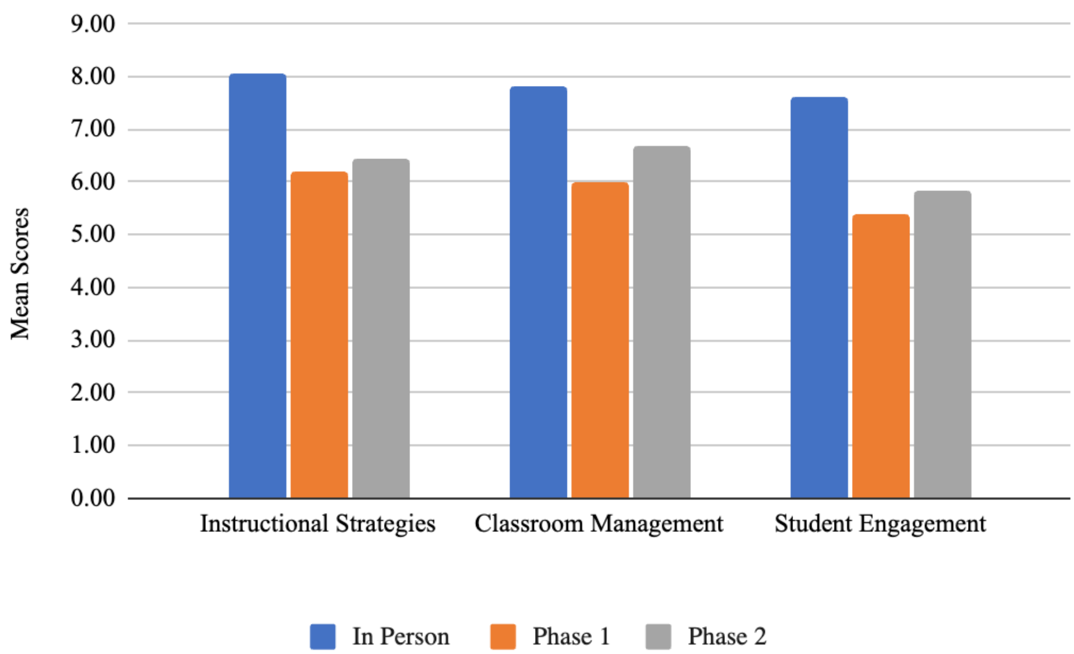
* $p < .001$.

With respect to self-efficacy and time during online teaching, paired *t*-tests were conducted for each subscale to compare phase 1 and phase 2. Teachers reported significantly greater self-efficacy for classroom management in phase 2 ($M = 6.83$, $SD = 1.34$) than in phase 1 ($M = 6.16$, $SD = 1.74$), $t(83) = -3.33$, $p < .01$. The effect size, Cohen's *d*, was 0.36, indicating a small effect. Similarly, self-efficacy for student engagement was significantly greater at phase 2 ($M = 5.85$, $SD = 1.34$) than at phase 1 ($M = 5.38$, $SD = 1.32$), $t(102) = -4.06$, $p < .001$, $d = 0.40$. The effect size, Cohen's *d*, was 0.40, indicating a small effect. Although teachers' efficacy scores for instructional strategies ($M = 6.27$, $SD = 1.28$) also increased by phase 2 ($M = 6.47$, $SD = 1.36$), the difference failed to reach statistical significance.

Figure 1 depicts how teachers had lower self-efficacy beliefs when first shifting to an online teaching modality (phase 1), but self-efficacy increased after several months of online teaching experience (phase 2). However, self-efficacy scores still failed to reach in-person levels even after several months of online teaching experience.

Figure 1

Mean Efficacy Scores (Max = 9) of In-Person, Online at Phase 1, and Online at Phase 2



Instruction Modalities

To examine the impact of time (phase 1 and phase 2) on online instruction experience, paired *t*-tests were conducted. Teachers reported engaging in significantly more hours of synchronous instruction at phase 2 ($M = 24.60$, $SD = 48.29$) compared to phase 1 ($M = 6.37$, $SD = 6.70$), $t(98) = -3.72$, $p < .001$. The effect size, Cohen's *d*, was 0.37, indicating a small effect. Although having decreased, asynchronous instruction was not significantly different between phase 1 and phase 2. The modality of instruction implemented in Ontario schools following the abrupt transition to online learning in March 2020 was largely directed by individual school districts, and in many cases by individual schools and teachers. As such, at phase 1, there was great variability in terms of the amount of time spent implementing asynchronous and synchronous instruction, with asynchronous instruction being the primary modality for many schools. However, by phase 2, districts had implemented instructional guidelines for synchronous instruction such that all teachers were required to implement a minimum number of synchronous instructional minutes per day, depending on the grade and/or subject.

Training

To compare teachers' reported technical and pedagogical training hours across phase 1 and phase 2, paired *t*-tests were conducted. Teachers had had significantly more technical training in online teaching by phase 2 (M = 26.40, SD = 55.51) compared to phase 1 (M = 9.50, SD = 17.45), $t(102) = -3.51$, $p = .001$. The effect size, Cohen's *d*, was 0.34, indicating a small effect. Teachers also reported significantly more pedagogical training for online teaching in phase 2 (M = 17.55, SD = 54.36) compared to phase 1 (M = 4.45, SD = 9.55), $t(98) = -2.42$, $p < .05$. The effect size, Cohen's *d*, was 0.24, indicating a small effect. However, no significant correlation between hours of training and teaching efficacy was observed, suggesting that the improvements in teachers' self-efficacy across phase 1 and phase 2 might be more effectively explained by other factors such as increased online teaching experience.

Differences Across Groups in Phase 1

Self-Efficacy

An ANOVA was performed to investigate any differences in self-efficacy for online teaching between groups of teachers. Post-hoc test results showed that in phase 1, virtual and private school teachers reported significantly higher self-efficacy for online teaching across all three OSTES subscales compared to public school teachers (Table 6). The effect size, eta squared (η2), was above 0.06 for all scales, indicating a medium to large effect.

Table 6

Teacher Self-Efficacy Scores for Public, Private, and Virtual Teachers During Phase 1

Scale		Public		Private		Virtual		F	η^2
		M	SD	M	SD	M	SD		
Instructional strategies*	Phase 1	5.80	1.40	6.76	1.23	6.36	1.33	15.78	0.079
	In-person	8.08	0.96	8.08	1.00	7.56	1.13	9.45	0.055
Classroom management*	Phase 1	5.42	1.89	6.72	1.67	6.79	1.23	25.59	0.137
	In-person	7.99	0.83	7.76	1.12	7.17	1.14	19.88	0.109
Student engagement*	Phase 1	4.99	1.38	6.06	1.26	6.10	1.14	32.50	0.151
	In-person	7.61	0.84	7.65	0.88	7.17	1.11	8.92	0.052

*$p < .001$.

For in-person teaching, post-hoc tests revealed that private and public school teachers reported significantly higher self-efficacy across all three OSTES subscales compared to virtual school teachers. The effect size, eta squared (η^2), was above 0.01 for all scales, indicating a small to medium effect.

Comparisons among teachers based on grades and subjects taught were explored but no significant differences were found. This result is not surprising as online teaching in an ERT setting is extremely different from in-person modalities, and the challenges of the two differ. Furthermore, these challenges may persist regardless of the grade levels and subjects teachers taught.

Instruction Modalities and Training

There was a significant effect of teaching context on synchronous teaching experience, $F(2,358) = 199.14$, $\eta^2 = 0.53$, $p < .001$. The effect size, eta squared (η^2), was 0.53, indicating a large effect. Post-hoc comparisons revealed that virtual school teachers had significantly more synchronous teaching experience ($M = 20.79$, $SD = 8.53$) than private ($M = 10.16$, $SD = 7.84$) and public school teachers, ($M = 3.56$, $SD = 4.29$). This result is expected since virtual school teachers spent the entirety of the pandemic teaching online and remained so regardless of lockdown status. These teachers therefore gained more experience in online teaching than other teachers. Interestingly, although private school teachers spent significantly more time teaching synchronously compared to public school teachers, when it came to time spent implementing asynchronous learning, public school teachers spent significantly more time ($M = 19.75$, $SD = 13.90$) than private school ($M = 11.19$, $SD = 12.02$) and also virtual school teachers ($M = 7.42$, $SD = 7.24$), $F(2,358) = 40.33$, $p < .001$. The effect size, eta squared (η^2), was 0.18, indicating a large effect.

There was a significant effect of teaching context on technical and pedagogical training. Post-hoc comparisons revealed that virtual school teachers received significantly more technical training ($M = 20.41$, $SD = 26.87$) than both public ($M = 8.20$, $SD = 12.55$) and private school teachers ($M = 8.82$, $SD = 17.10$), $F(2,369) = 15.47$, $p < .001$. The effect size, eta squared (η^2), was 0.077, indicating a medium effect. Virtual school teachers also received more pedagogical training ($M = 17.15$, $SD = 39.43$) than public ($M = 4.93$, $SD = 9.10$) and private school teachers ($M = 4.47$, $SD = 6.97$), $F(2, 358) = 10.64$, $p < .001$. The effect size, eta squared (η^2), was 0.056, indicating a small effect.

Discussion

This study offers insight into the promise and challenges of online education, revealing a narrative of positive—though perhaps insufficient—improvement in the perceived self-efficacy of teachers in Ontario, who were forced to suddenly adapt to virtual teaching in the context of an unprecedented disruption. The study results also present consequential information for teacher education, illustrating how teachers gained expertise, comfort, and efficacy in administering curricula online with the passage of time. The data collected conveys the increasing confidence and capability of teachers to engage students, manage classrooms, and deliver instruction in an unusual and difficult situation. Nevertheless, even as phase 2 teaching efficacy exceeded self-reported efficacy in phase 1, phase 2 results continue to lag behind perceived self-efficacy of in-person teaching, demonstrating the persisting limitations educators experience in online learning environments. This result is contrary to previous studies regarding online classroom management, where teachers found that classroom management was easier online (Dreon et al., 2018; Lin & Zheng, 2015). Lin and Zheng (2015) found that classroom management among language teachers was easier online than in-person as there was less time wasted establishing rules which allowed teachers to focus more on teaching. However, it should be noted that these teachers worked in a virtual school prior to the pandemic. This difference emphasizes the extent of the impacts of a sudden and abrupt shift into online teaching on teachers' self-efficacy. This sudden shift to online teaching, characterized by ERT in the spring of 2020, significantly impacted teachers' self-efficacy as teachers' lack of preparedness for online teaching caused their overall self-efficacy to decrease (Cataudella et al., 2021; Pressley & Ha, 2021; Yenen & Çarkit, 2021). The backdrop of a global pandemic may have also impacted teacher outcomes in classroom management. Such teachers may have found it more challenging to manage their classrooms when circumstances were out of their control.

Teachers' self-efficacy beliefs increased significantly in the domains of classroom management and student engagement with the passage of time, however, efficacy for instructional strategies had not significantly increased by phase 2. Hours of training was not correlated with teaching efficacy which suggests that over time, the experience gained teaching online improved teachers' self-efficacy beliefs rather than any technical or pedagogical training. While no significant association was found between teacher training and self-efficacy, there seemed to be a positive association between increased experience and higher self-reported rates of efficacy, as over time, the experience teachers gained from teaching online may have improved their feelings of self-efficacy. These results are somewhat corroborated by previous studies. Lee and Tsai (2010) found a positive correlation between experiences of web-related pedagogical practice and self-efficacy in these areas. Robinia and Anderson (2010) found that self-efficacy in nurse educators was related to the number of experiences teaching online. The more time teachers spend teaching online, the greater their efficacy was in managing their classrooms. Studies have shown that self-efficacy for online teaching increased following the COVID-19 experience, as teachers were no longer experiencing the challenges and negative effect tied to ERT (Baroudi & Shaya, 2022). Horvitz et al. (2015) found that "semesters taught online" was a significant predictor for higher levels of efficacy in classroom management, but not for instructional strategies or student engagement (p. 312). Skills in classroom management and student engagement may be more easily gained with the passage of time whereas instructional strategies may require more targeted interventions that address specific competencies. Another contributing factor to higher efficacy may have been the standardization of time dedicated to synchronous learning which had been implemented in Ontario by phase 2 of this study, which led to lower variability in asynchronous learning.

Further quantitative analysis of variances among public, private, and virtual teachers also presents meaningful data. In phase 1, private school teachers reported higher levels of self-efficacy in online teaching, and higher levels of synchronous teaching. Although private school teachers spent significantly more time teaching synchronously compared to public school teachers, public school teachers spent significantly more time than both private school and virtual school teachers implementing asynchronous learning in phase 1, which could be a possible explanation for their lower scores of self-efficacy in all three composites compared to private and virtual teachers at that time. A possible reason why asynchronous lectures could affect teaching efficacy is the less personal nature of the format.

Asynchronous lectures can be isolating as there is less direct and habitual interaction between teachers and students. Zagorski (2011) found that teachers felt more isolated teaching online than in-person, and that feelings of isolation experienced teaching online were related to lower self-efficacy than teaching in-person. This result contrasts with public school teachers' in-person self-efficacy, which was similar to or higher than private school teachers. The significant drop in self-efficacy in public school teachers upon shifting to an online format should be further investigated, and future research could examine possible correlations between synchronous online learning and efficacy, divergences between the experiences of public and private teachers throughout the pandemic, and hybrid methods.

There were no significant differences between teachers based on grades and subjects taught. As online teaching in an ERT setting and in-person teaching are extremely different and the challenges between the two differ for all teachers, this result is not unexpected. Furthermore, challenges pertaining to online teaching may persist no matter the grade level and subjects taught among teachers. This result is similar to the findings of Menabò et al. (2022), who found no differences in online teaching self-efficacy between primary and secondary teachers.

As online self-efficacy for classroom management and student engagement significantly increased with more experience, teacher education programs hoping to improve the confidence of future online educators could deploy experiential curricula, offering preservice teachers the chance to learn firsthand the challenges of virtual education. Future teacher education programs post-COVID regarding online learning should also include elements that focus more on the pedagogy of online teaching including instruction in lesson planning, teaching curriculum content, and online assessment. This need for further pedagogical training is supported by the research of Meisner & McKenzie (2023) in their study of 699 teachers across nine states in the USA, exploring teachers' perceptions of self-efficacy for online teaching during the COVID-19 pandemic. Skills related to instructional strategies are not easily gained by experience unlike classroom management and student engagement, indicating a need for professional development programs targeting online instructional strategies in particular, and the necessity to address the competencies related to online instructional strategies. School boards could implement professional development programs for teachers interested in online teaching. Teachers can feel prepared and equipped for online teaching modalities with adequate training; the rapidness of the transition into online teaching set against a backdrop of uncertainty during a global pandemic has no doubt influenced their online teaching self-efficacy. School boards can also support teachers as they go through online teacher development programs so that they persist through the program long enough to gain adequate experience and thus teaching efficacy.

Limitations

This study has potential limitations. Quantitative data collected at two distinct time periods were compared, an analytical abstraction that assumes these two unique situations are commensurable. Secondly, only quantitative data were gathered, meaning that qualitative data, which may offer important insight into the aspects of teaching efficacy and experience that are not captured by quantitative analysis, were not present. The exclusion of qualitative data could limit the scope and rigor of research results, as although representing human experience numerically is often illuminating, it necessitates the exclusion of data that cannot be expressed in this form. Qualitative analysis of teacher experiences could complement the quantitative data this study gathered, potentially elaborating on some of the patterns identified. Investigating these questions will offer additional information to teacher education programs hoping to offer teachers the best possible preparation for administering curricula online. Finally, not all study participants returned to participate in phase 2, meaning that the data collected in the second phase of the study were limited to a smaller sample size than the data collected in the first phase. This change in the data pools limits the commensurability of the results reported in each respective phase by participants.

Conclusion

Teaching efficacy is an important component of student and teacher outcomes. The results of this study show that the sudden shift to online learning during the pandemic has implications for teacher self-efficacy in public, private, and virtual school teachers, and reveals potential next steps for teacher education programs. Teachers become more comfortable managing online classrooms and engaging students as time goes on, but nevertheless, teachers' efficacy scores are significantly higher in-person regardless of experience gained teaching online. Although self-efficacy for instructional strategies can improve with experience, evidence from this study shows that these skills are less transferable from in-person to online than skills in student engagement and classroom management. Thus, future teacher education programs should focus particularly on skills relating to instructional strategies in online teaching. Furthermore, more in-depth comparisons of experiences between public and private teachers throughout the pandemic may reveal important ramifications on support and resources, and uncover additional information important for equitable teacher education programs.

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STEM Teacher Candidates' Preparation for Online Teaching: Promoting Technological and Pedagogical Knowledge

Préparer les futurs enseignants en STIM à enseigner en ligne : comment promouvoir les connaissances technologiques et pédagogiques?

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Abstract

Emergency remote teaching during the COVID-19 pandemic has shed light on pedagogical challenges that require the immediate attention of teacher education programs. This paper focuses on teacher candidates' preparation to teach online in a STEM curriculum and pedagogy course in a teacher education program at a Canadian university. The authors present a two-phase study of two cohorts of teacher candidates enrolled in this course and explore 1) their perceptions of the dynamics and effectiveness of online teaching as a teaching modality, and 2) the impact of the course on their technological and pedagogical skills necessary for online teaching. Quantitative and qualitative data were collected through pre- and post-surveys administered online at the beginning and end of the course. Findings suggest that teacher candidates' engagement with course content resulted in a notable improvement in their views toward online teaching as a teaching modality, pedagogical approaches, and personal abilities utilizing innovative online teaching strategies. This research emphasizes the necessity for comprehensive training programs that enhance teacher candidates' technological competencies while simultaneously refining their pedagogical methodologies for online settings. Implications for teacher education research and practice are discussed.

Keywords: online teaching, STEM teaching, teacher education, TPACK

Résumé

L'enseignement à distance qui a dû s'organiser en urgence lors de la pandémie de COVID-19 a mis en lumière les défis pédagogiques auxquels les enseignants ont été confrontés et la nécessité de modifier dès maintenant les programmes de formation des enseignants. Cet article porte sur la préparation des étudiants à l’enseignement en ligne dans le cadre d’un cours de deuxième année en STIM et en pédagogie au sein d’un programme de formation des enseignants dans une université canadienne. Les auteurs présentent une analyse en deux phases de deux cohortes d’étudiants en enseignement inscrits à ce cours et explorent 1) leurs perceptions de la dynamique et de l’efficacité de l’enseignement en ligne en tant que modalité d’enseignement, et 2) les répercussions du cours sur les compétences technologiques et pédagogiques nécessaires à l’enseignement en ligne. Des données quantitatives et qualitatives ont été recueillies par le biais d’enquêtes *avant* et *après* effectuées en ligne au début et à la fin du cours. Les résultats montrent que le contenu des cours a permis aux étudiants de renouveler considérablement leur vision de l’enseignement en ligne en tant que modalité pédagogique, leurs approches pédagogiques et leurs capacités personnelles à utiliser des stratégies d’enseignement en ligne novatrices. Cette étude souligne la nécessité de mettre en place des programmes de formation approfondis qui permettent d’améliorer les compétences technologiques des candidats à l’enseignement tout en affinant leurs méthodes pédagogiques dans un contexte d’enseignement en ligne. Nous analysons les implications pour la recherche et la pratique dans le domaine de la formation des enseignants.

Mots-clés: enseignement en ligne, enseignement des STIM, formation des enseignants, TPACK

Introduction

Emergency remote teaching (ERT) is the rapid transition to online teaching based on an urgent resolution to keep instructional continuity with students (Kang et al., 2021). During the COVID-19 pandemic, ERT had significant implications for practice as it highlighted gaps in both teacher candidates’ (TCs’) and in-service teachers’ digital literacy, specifically their confidence, motivation, and competence in using educational technologies in online environments (Burns et al., 2020; DeCoito & Estaiteyeh, 2022b). For instance, research on ERT in Canada highlights challenges facing science, technology, engineering, and mathematics (STEM) teachers, including lack of digital resources and insufficient preparation that negatively affected their teaching and assessment strategies in online settings. Teachers reported their reliance on teacher-centred and less creative strategies as they had to prioritize teaching content with minimal attention to pedagogies (DeCoito & Estaiteyeh, 2022a). Additionally, the 2023 Pan-Canadian report on digital learning trends in Canadian postsecondary education highlights that the expected greater technology integration in teaching and learning raises concerns about faculty skills and know-how to teach in digital environments (Johnson, 2023).

Hodges et al. (2020) explain that ERT implemented hurriedly, with bare minimum resources and limited time must be distinguished from quality online teaching that is based on effective planning and careful instructional design. Hence, educators must now shift their focus to understand the outcomes of this transition and its impact on teachers’ competencies in online pedagogy, considering the possibilities associated with current technologies and online resources (Carrillo & Flores, 2020). In harmony, at the level of teacher education programs, the pandemic has created opportunities to reconceptualize online pedagogy as a critical component of teacher preparation (Alvi, 2023).

Research on STEM TCs’ preparation in online teaching especially in the Canadian context is limited, despite a few studies that accompanied the pandemic (e.g., Bourgoin, 2023; Tembrevilla &

Milner-Bolotin, 2019; Van Nuland et al., 2020). Given this research gap, and the premise that future teachers must not only be technologically adept but also skilled in digital pedagogy (Aslan & Zhu, 2017), this study addresses teacher preparation for the challenges and opportunities inherent in online learning environments. In this paper, the authors advocate for the necessity for comprehensive training programs that enhance TCs' technological competencies while simultaneously refining their pedagogical methodologies for online settings. The research takes place in a STEM curriculum and pedagogy course in a teacher education program at a university in Ontario. This course was initially developed as a hybrid course, enriched with digital technologies and resources, to support TCs' technological literacy and pedagogical frameworks in STEM education (DeCoito, 2023). However, due to the abrupt pivot to ERT, it was noted that TCs were ambivalent and exhibited anxiety toward online teaching. As such, the STEM course was a preferred context for this research, given that it focuses on curriculum and pedagogy aligned with technological integration, thus offering opportunities for observing the interplay between technology and pedagogy.

Research Questions

The study focuses on TCs' preparation to teach online in a STEM curriculum and pedagogy Year-2 course in a teacher education program at a Canadian university. The authors present a two-phase study of two cohorts of TCs enrolled in this course to explore its impact on TCs' technological and pedagogical skills necessary for online teaching. This paper addresses two research questions:

1. How do TCs perceive online teaching as a teaching modality?
2. What is the impact of the course on TCs' technological and pedagogical skills necessary for online teaching?

Literature Review

Teacher Candidates' Preparation in Online Teaching

The last few years have witnessed an increased adoption of online teaching (Barbour, 2018). Many studies around the world, for instance, in Canada (Burns et al., 2020), United States (Long et al., 2022), Germany (Dilling & Vogler, 2023), Turkey (Bahcivan et al., 2019), South Korea (Han et al., 2017), and UAE (Hojeij & Baroudi, 2021) have demonstrated positive effects of online teaching preparation and training on TCs' and in-service teachers' readiness to engage in this teaching modality. In this section, we describe in detail several interventions from the literature that shed light on the significance of TCs' preparation for online teaching.

A seminal study by Aslan and Zhu (2017) investigated the role of pedagogical training courses in fostering 599 TCs' information and communications technology (ICT) integration. Findings indicated that while TCs demonstrated a positive attitude towards using ICT in their teaching and competence in basic ICT skills (e.g., presentation skills and word processors), they were not competent in integrated ICT skills (e.g., utilizing simulated tasks for experiments). This study concluded that pedagogical knowledge, ICT related courses, and TCs' perceptions were three significant factors predicting TCs' integration of ICT in their teaching, compared to other variables such as attitudes toward technology, prior ICT experience, and gender. Further, Aslan and Zhu (2017) noted that teacher training programs played a significant role in facilitating TCs' integration of ICT in their teaching and that ICT related courses must consider subject curricula and accompanying pedagogical knowledge. Along the same line, Han et al. (2017) explored technology-centred teaching experiences and their effects on TCs' self-efficacy and intention to use technology. The findings revealed that the technology-centred student experience increased TCs' self-efficacy regardless of their initial beliefs. Han et al. concluded that teachers with traditional pedagogical beliefs significantly benefited from exposure to technology-rich teaching experiences as it encouraged them to integrate technology in their future teaching. Similarly, Dilling and Vogler (2023) examined the impact of a training course in preparing TCs to independently create an online learning unit with Moodle platform. This training was successful in changing the views of TCs especially in creating online content and introducing a topic using the platform, as they found the platform capable of providing individualized support to students through online learning resources. Milner-Bolotin (2019) maintained that TCs and in-service teachers must be given the opportunity to collaboratively design technology-enhanced STEM education resources that are relevant to their teaching contexts. Such resources need to highlight relevant theoretical underpinnings, the evaluation methods for their pedagogical effectiveness, and the purpose of using technology (Milner-Bolotin, 2019).

Collectively, the aforementioned studies outline the critical role of TCs' engagement with online teaching as learners before they utilize it as teachers. However, it is important to note some fundamental factors for the success of such programs. Schubatzky et al. (2023) emphasize that a strong foundation in pedagogical content knowledge (PCK) is essential for the development of TCs' digital media PCK. Additionally, instructors must be cognizant of individual differences among TCs with respect to their experience with digital technologies, and hence must differentiate the training to ensure that TCs are acquiring its benefits relative to their level (Schubatzky et al., 2023).

Teacher Candidates' Pedagogical Views of Online Teaching as a Teaching Modality

During the pandemic, several researchers examined TCs' views of the effectiveness of online teaching as a teaching modality. In Canada for example, studies spanned provinces and territories, including British Columbia (Tembrevilla & Milner-Bolotin, 2019), New Brunswick (Bourgoin, 2023), Alberta (Burns et al., 2020; Burron & Pegg, 2021), Ontario (Van Nuland et al., 2020), and Québec (Raby et al., 2020). On a positive note, online teaching was viewed by TCs as more flexible and adaptable to change than ever before (Coskun Karabulut et al., 2023; Van Nuland et al., 2020). Ali and Nath (2023) argued that online teaching allowed TCs to acquire new skills and knowledge and enhance their ability to self-regulate their learning. In another study, TCs also reported that their technological knowledge was expanded and their ability and confidence in using technological resources increased as they were able to incorporate a variety of online resources in their teaching (Hojeij & Baroudi, 2021). Similarly, Brinia and Psoni (2022) reported that TCs became acquainted with new technologies in education and developed useful skills for their future teaching - including adaptability, flexibility, and managing students' interactions in online settings - that they would not have developed in a traditional setting. Alvi (2023) reported similar findings in which TCs demonstrated improvements in the design (lesson plans), direct instruction (technological skills and methodology), and facilitation of online teaching (classroom interaction), despite their initial limited beliefs, resistance to change, and unwillingness to engage with technologies.

On the other hand, research findings revealed several challenges reported by TCs in online teaching such as lack of collaboration and interaction with instructors and peers (Ali & Nath, 2023; Margaliot & Gorev, 2020). Additionally, TCs found the online environment to be challenging with respect to individualizing instruction, limiting students' physical movement, and limiting teachers' creativity. Teacher candidates acknowledged their lack of preparation in designing interactive online lessons and highlighted the need for better preparation to incorporate online games, for example, into their instructional practices (Hojeij & Baroudi, 2021). Brinia and Psoni (2022) reported challenges inherent in online teaching in terms of reading students' body language, facilitating group work, and maintaining experiential learning activities. Moreover, TCs indicated a preference for traditional classrooms where they would experience more robust classroom interactions and less pedagogical challenges (Alvi, 2023). Accordingly, Alvi recommended that TCs must be offered training and support to enhance their digital literacy skills and experiment with different teaching approaches and technologies related to their own practice to help them overcome stated challenges. Similarly, Margaliot and Gorev (2020) suggested that online pedagogy courses must create a real need for collaboration between TCs so that they recognize its practical aspects and significance.

Furthermore, Burron and Pegg (2021) reported that TCs were generally inefficient in their searches for online teaching resources. They concluded that TCs required online resources that are complete, provide background and context, and are modifiable, aligned with curriculum outcomes, and provide appropriate pedagogical content knowledge to use the resources effectively. Hence, TCs must be prepared to search for and recognize those resources efficiently, as well as how to construct resources that are useful and organized in a way that is readily accessible (Burron & Pegg, 2021). Despite these challenges, Burns et al. (2020) reported that TCs acknowledged that they require online instructional skills for their future teaching practice, despite their initial thoughts that online instruction is impractical, unrelated to their teaching practice, and just a temporary solution. Hence, Burns et al. concluded that there is a need to consider online pedagogy as a more central part of TCs' education.

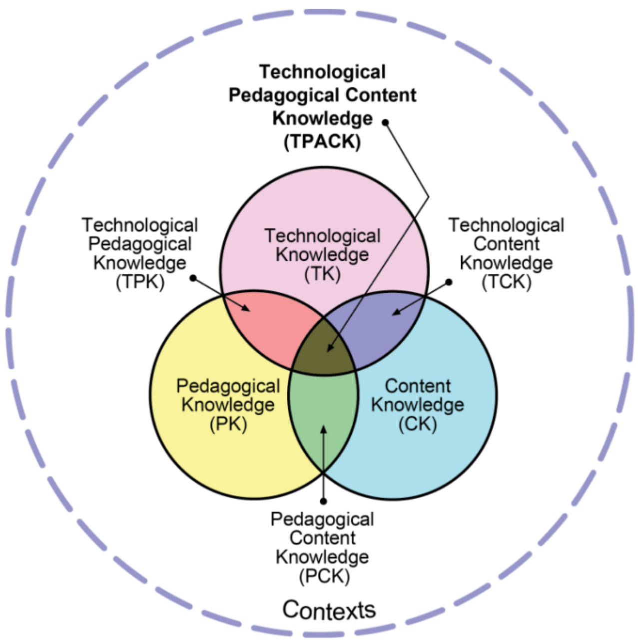
Overall, these studies reiterate the need for teacher training programs that promote and enhance technological competencies and pedagogical skills needed for online teaching. These programs must also address TCs' views of online teaching as a teaching modality, especially that such perceptions significantly predict and influence TCs' integration of ICT in their future teaching.

Theoretical Framework

This research is informed by the technological, pedagogical, and content knowledge (TPACK) framework (Mishra & Koehler, 2006) and the digital competencies for teaching in science education (DiKoLAN) framework (Von Kotzebue et al., 2021). Shulman (1987) defines pedagogical content knowledge as the "capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful yet adaptive to the variations in ability and background presented by the students" (p. 15). Mishra and Koehler (2006) extend Shulman's PCK to integrate technology into teacher's pedagogy. This model of technology integration in teaching and learning is known as TPACK (Koehler et al., 2013) (Figure 1).

Figure 1

TPACK Framework



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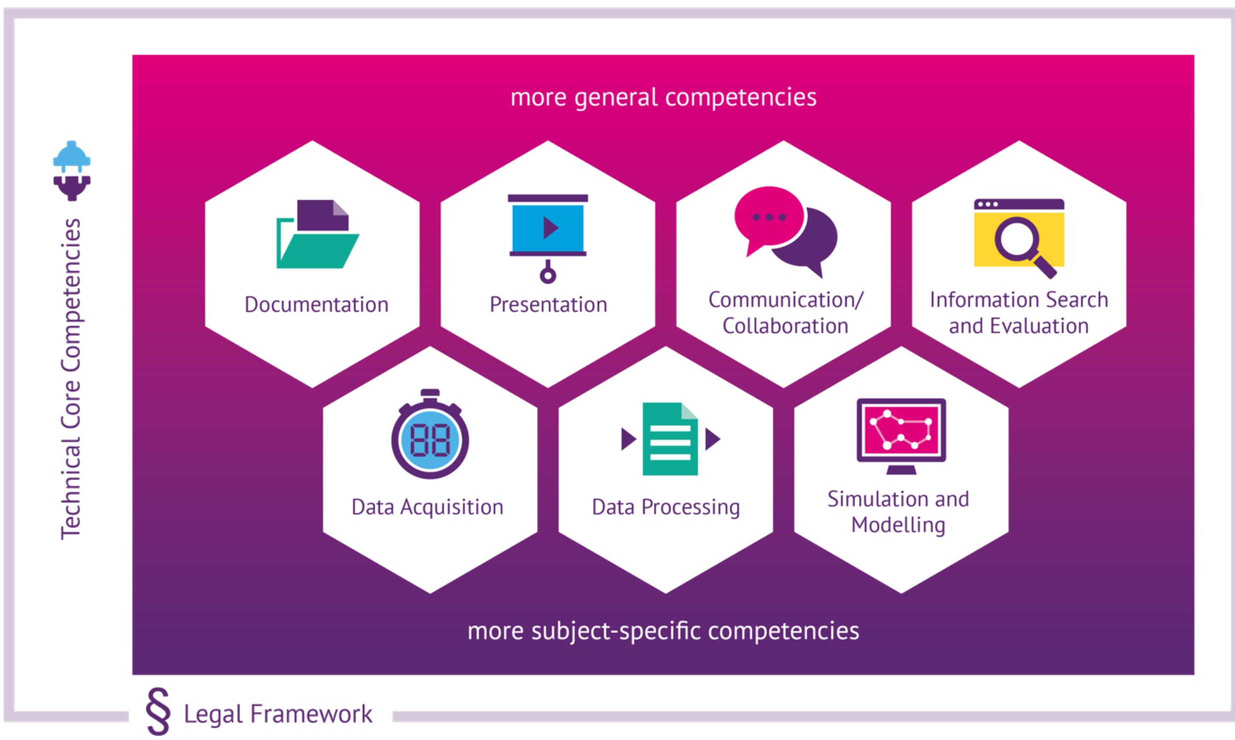
In teacher education programs, TCs may develop their TPACK through dedicated educational technology courses and by incorporating content-specific teaching methods (Hofer & Grandgenett, 2012). Teacher candidates' training plays a significant role in promoting their TPACK self-efficacy (Joshi, 2023) and enhancing their TPACK levels as they connect their content areas, content-specific pedagogies, and available technologies (Tondeur et al., 2020). Joshi (2023) highlights that subject-based professional development practices for integrating technology into the curriculum can support teachers in improving their technology self-efficacy. Thus, such contextualization of technological skills is crucial and provides additional rationale for choosing the STEM curriculum and pedagogy course as a setting for the research study underlying this paper.

On another note, Von Kotzebue (2022) argue that subject-specific description of TPACK has been limited. Hence, they propose a framework that is subject-specific for science TCs to design and implement digitally supported science education. This framework, titled Digital Competencies for Teaching in Science Education (DiKoLAN) is a foundational step towards domain-specific structuring and assessment of TPACK. DiKoLAN includes four general competency areas that are essential for digitally supported teaching in all subjects (documentation, presentation, communication/collaboration, and information search and evaluation) and three science-specific competency areas (data acquisition, data processing, and simulation and modeling) (Figure 2). Additionally, each of the seven competencies is described by competency expectations that are structured with reference to the four technology-related dimensions of the TPACK framework (TPACK, technological pedagogical knowledge- TPK, technological content knowledge- TCK, and technological knowledge- TK) and three levels of performance (Name, Describe, Use/Apply). Von Kotzebue et al. (2021) recommend utilizing the DiKoLAN framework to guide the creation of science curricula in teacher education as well as evaluating TCs' competency levels and development processes. A few research studies have recently adopted this novel framework (e.g., Henne et al., 2022; Krug et al., 2023; Müller et al., 2022; Schubatzky et al., 2023). Our paper utilizes aspects of the DiKoLAN framework as an extension of the TPACK framework in analyzing the development of TCs' STEM-education pedagogical and technological skills, to better prepare them for online teaching in the future.

Figure 2

DiKoLAN Framework: Workgroup Digital Core Competencies



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Methodology

Research Design and Participants

The research adopts a multiple-case study research design (Yin, 2014). Each case is one cohort of TCs enrolled in a STEM curriculum and pedagogy course, in the second year of a teacher education program at a university in Ontario, Canada. Participants in Cohort 1 are 24 TCs who completed the course online in the academic year 2020-2021. Participants in Cohort 2 are 34 TCs who completed the course in a hybrid format (both in-person and online components) in the academic year 2021-2022. All

TCs were in the intermediate-senior division with teachable subjects in one or two STEM disciplines (science, biology, physics, chemistry, health and physical education, and math).

The study occurred in a 12-week curriculum and pedagogy in STEM course in the STEM specialty focus in a teacher education program. The course was designed to promote TCs' use of digital technologies and enhance their preparation in online teaching. For instance, the course offered theoretical and practical lessons on educational technologies and TPACK. Additionally, the online delivery of course components provided opportunities to practice and model online teaching pedagogies. Course assignments focused on creating and incorporating digital technologies in K-12 teaching such as digital timelines (DeCoito & Vacca, 2020), digital case studies, digital video games, and developing digital STEM curriculum websites (DeCoito, 2023). In these assignments, TCs assumed the dual roles of curriculum developers and learners in STEM education to engage with these resources from both perspectives.

Data Sources

Quantitative and qualitative data were collected through pre- and post-surveys administered online to TCs at the beginning and end of the course, respectively. This paper reports on 25 5-point Likert scale statements (1=strong disagreement to 5=strong agreement) in both surveys and two open-ended questions in the post-survey. The survey statements and questions addressed TCs' technological and pedagogical competencies in online teaching, their pedagogical perceptions of online teaching as a teaching modality, and reflections on the effectiveness of the course.

Sample Likert scale items included:

- *I can use more creative teaching methods and ideas when teaching online.*
- *My major concern in online classes is to ensure that the course content is being taught (achieving the curriculum objectives) regardless of the teaching methods.*
- *I find it challenging to integrate student-centred and inquiry-based teaching methods in my online teaching (such as group discussions, online activities and simulations, virtual labs, etc.).*

The two open-ended questions, developed by the research team based on the literature and course activities include:

- *To what extent do you think this course was successful in terms of teaching you specific pedagogical and technological skills to use in online teaching? Reflect on both: the fact that you have learned the course completely online, and the fact that it integrated specific digital components.*
- *List some online teaching skills that you feel need ongoing improvement or more reinforcement despite the material offered in this course.*

Data Analysis

The authors used Qualtrics survey system and Microsoft Excel to analyze the quantitative data resulting TCs' responses to surveys' Likert scale statements. This analysis included calculating counts, averages, standard deviations, percentages, and differences between pre- and post-results. An inductive thematic analysis (Creswell & Creswell, 2018; Schreier, 2013) was conducted to analyze the qualitative data resulting from TCs' responses to the open-ended questions. Two of the researchers collaboratively synthesized initial codes based on the frequency count in TCs' responses. Thereafter, the authors grouped similar codes into themes to draw conclusions (Gall et al., 2005). To ensure the trustworthiness of the analysis (Creswell & Creswell, 2018), the three research team members convened to review and finalize the themes.

Results

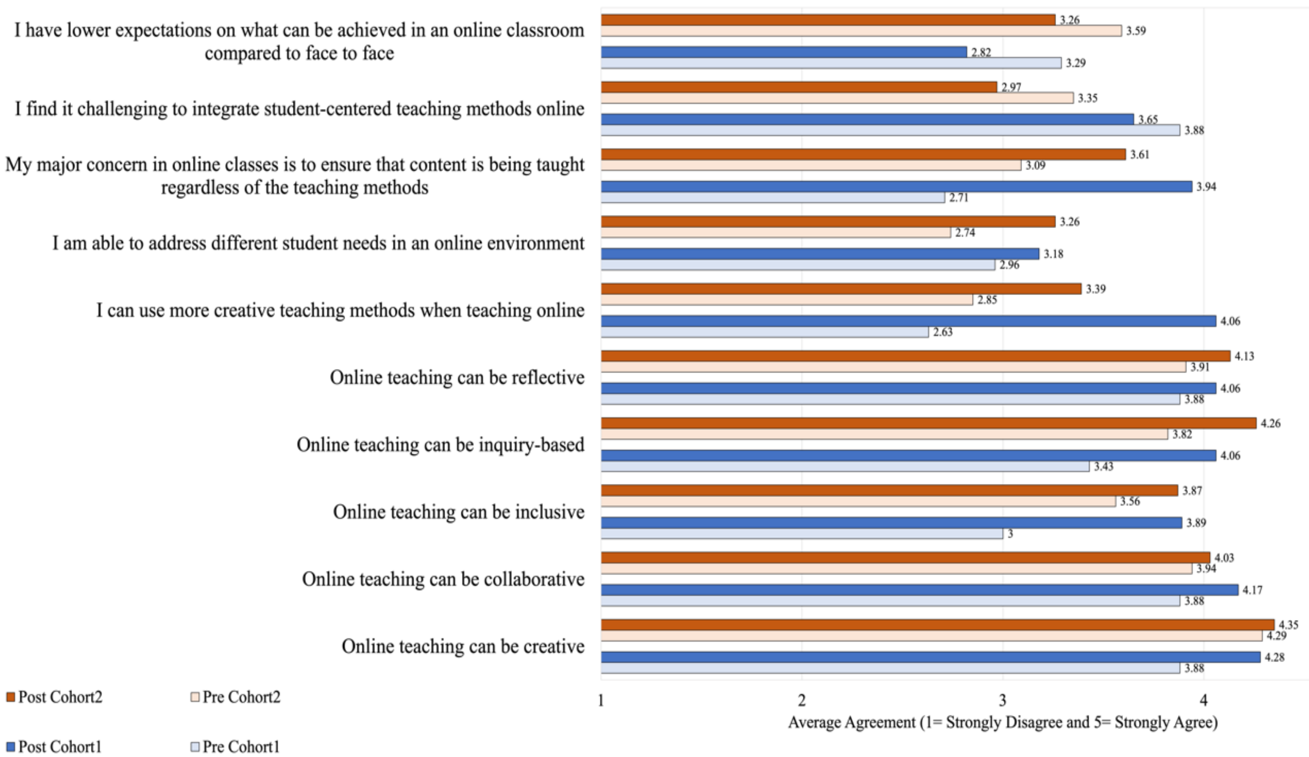
How TCs Perceive Online Teaching as a Teaching Modality

Figure 3 highlights the average responses of TCs' initial and final pedagogical views toward online teaching. Pre-survey findings indicate that TCs held relatively negative views of online teaching. Teacher candidates mostly neither agreed/disagreed or slightly agreed that online teaching can be reflective, inquiry-based, inclusive, collaborative, and creative. At the end of the course, the average agreement increased significantly on all indicators across both cohorts. For both cohorts, the statements that showed the greatest positive difference are: "Online teaching can be inquiry-based" (average increased from 3.43 to 4.06 in Cohort 1 and 3.82 to 4.26 in Cohort 2) and "inclusive" (average increased from 3 to 3.89 in Cohort 1 and 3.56 to 3.87 in Cohort 2). It is also worth noting that pre-survey pedagogical perceptions toward online teaching were consistently more positive in Cohort 2 compared to Cohort 1 on all five indicators. Moreover, the averages on post-survey responses on four indicators (creative, collaborative, inquiry-based, and reflective) were all above 4 indicating agreement. Only one indicator (inclusive) recorded 3.89 in Cohort 1 and 3.87 in Cohort 2 which is very close to the agree level.

Furthermore, TCs agreed that they can use creative teaching methods and ideas (average agreement increased in the post-survey compared the pre-survey from 2.63 to 4.06 in Cohort 1 and from 2.85 to 3.39 in Cohort 2). They also agreed that through differentiating instruction or other methods, they can address different student needs and academic abilities in an online environment (average agreement increased from 2.96 to 3.18 in Cohort 1 and from 2.74 to 3.26 in Cohort 2). Additionally, TCs' agreement decreased on statements related to i) finding it challenging to integrate student-centred and inquiry-based teaching methods in online teaching (such as group discussions, online activities and simulations, virtual labs, etc.), ii) lowering expectations on what can be achieved in an online classroom when compared to a face-to-face setting (in terms of curriculum coverage and teaching methods), and iii) assessing students' understanding online, especially certain skills such as higher order thinking, cooperative learning, or hands-on learning skills. Taken together, these findings indicate an improvement in what TCs perceive as achievable in online teaching.

Figure 3

Teacher Candidates' Initial and Final Pedagogical Perceptions of Online Teaching



However, despite improvement on being able to address different student needs online, the post-survey numbers are closer to 3 (neither agree or disagree), and thereby are not close to the agreement level in both cohorts. Similar results are observed on ability to use creative teaching methods online in Cohort 2. Additionally, TCs' agreement with the statement "My major concern in online classes is to ensure that the course content is being taught (achieving the curriculum objectives) regardless of the teaching methods" increased to reach 3.94 in Cohort 1 and 3.61 in Cohort 2 approaching an agreement level in both cohorts, hence not showing improvement upon comparing post- to pre-survey results.

Overall, TCs expressed an improvement in their pedagogical views of online teaching which entail how they describe online teaching. In the next section, findings related to TCs' perception of the impact of the online STEM course on their technological and pedagogical skills will be highlighted.

Impact of the Course on TCs' Technological and Pedagogical Skills for Online Teaching

Figure 4 highlights TCs' account of the effectiveness of the course on their TPACK across both cohorts. In the post-survey, TCs indicated that they found the course either helpful or very helpful in i) learning to use new software programs (76% in Cohort 1 and 90% in Cohort 2), ii) improving their use of familiar software programs (64% in Cohort 1 and 90% in Cohort 2), iii) organizing and presenting ideas online (65% in Cohort 1 and 84% in Cohort 2), iv) applying and utilizing technology in their teaching (70% in Cohort 1 and 87% in Cohort 2), v) learning methods to increase student engagement in online settings (70% in Cohort 1 and 84% in Cohort 2), and vi) learning methods to increase student agency in online settings (59% in Cohort 1 and 74% in Cohort 2). Overall, it is evident that the course had a positive impact on the stated technological and pedagogical skills necessary for online teaching. This impact was consistent across both cohorts, while noting that Cohort 2 perceived the impact more positively compared to Cohort 1.

Figure 4

Teacher Candidates' Account of the Influence of the Course on Various Aspects of Their Technological and Pedagogical Skills

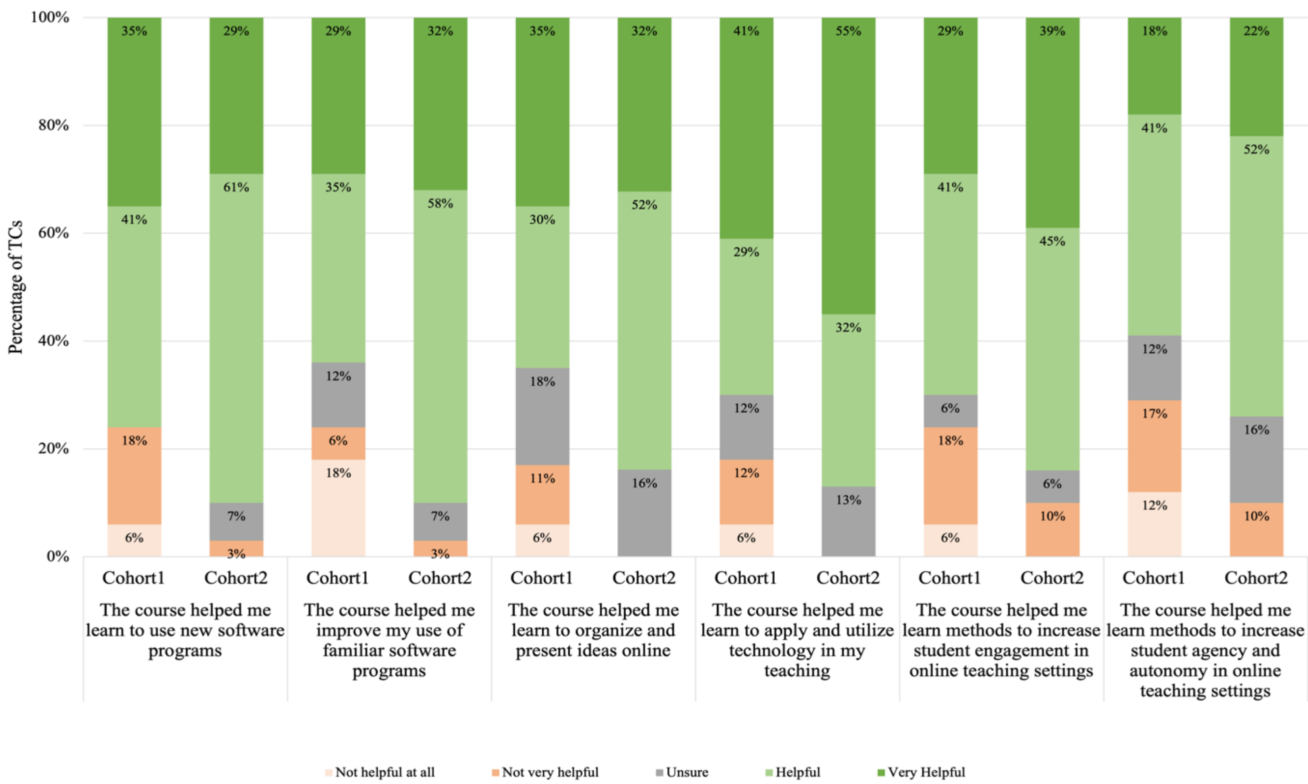


Table 1 details the course effectiveness in terms of enhancing TCs' online teaching and assessment strategies. Teacher candidates self-assessed their familiarity with and competence using various online pedagogical strategies. Comparing pre- to post-survey data, TCs' scores improved in both cohorts on almost all online teaching strategies: synchronous teaching (facilitating direct instruction with students), self-directed learning (sending resources and materials for students to study on their own), virtual labs, online simulations and digital games, online discussion or chat tools, content creation software such as Moviemaker (with exception of Cohort 1), and website creation. Similarly, TCs' scores improved on items related to online assessment strategies, such as online quizzes and tests (with exception of Cohort 1), lab or simulation reports, and content creation by students for assessment including videos, presentations, websites, and ePortfolios.

Table 1

Percentages of TCs Stating That They are Familiar with and Competent in Using Specific Teaching and Assessment Strategies Online

Strategies	Cohort 1		Cohort 2	
	Pre-survey (N=24)	Post-survey (N=18)	Pre-survey (N=34)	Post-survey (N=31)
Synchronous teaching	63%	89%	53%	87%
Self-directed learning	79%	83%	74%	77%
Virtual labs	33%	72%	15%	61%
Online simulations and digital games	46%	89%	47%	58%
Online discussion or chat tools	75%	89%	61%	71%
Content creation software	92%	89%	71%	84%
Website creation	21%	83%	12%	58%
Online quizzes and tests	83%	82%	71%	90%
Lab or simulation reports	29%	76%	29%	58%
Content creation by students for assessment	46%	71 %	47%	77%

Overall, the survey findings show a notable improvement in TCs' technological and pedagogical skills and abilities utilizing innovative teaching and assessment strategies in online teaching. Furthermore, to provide detailed insight on their survey responses, TCs responded to two open-ended questions in the post-survey. Since both cohorts showed similar trends in findings emanating from the quantitative survey responses, their open-ended responses were aggregated for the qualitative analysis. First, TCs elaborated on the extent to which they perceived the course successful in terms of modeling specific pedagogical and technological skills to use in online teaching. Common themes included: 1) learning specific skills needed for online teaching (16 out of 29 responses) and 2) learning about specific tools and resources (9 out of 29 responses).

In relation to the skills needed for online teaching, TCs mentioned communication and collaboration in online environments, choosing and using digital resources (course emphasis on online teaching pedagogies), comfort using new software, organization, and providing feedback to students. Teacher candidates reflected on pedagogy and how the course incorporated those skills in its content and assignments. They said:

I found this course very successful in teaching specific pedagogical and technological skills to use in online teaching. I've learned a number of new digital tools as well as pedagogical skills such as teaching through timelines, case studies and building an online website/digital resource for teaching. (TC1)

Pedagogy was a huge focus and the instructor helped me integrate this with technological skills. This was effective both in-person and online. This was one of the only courses I've had that clearly discussed pedagogy and what it means to develop pedagogical skills to become more effective teachers. (TC2)

This course was successful in teaching me what to look for, to be critical of technology (don't just use it to use it), and how to align curriculum to online tech. (TC4)

They also reflected on the fact that the course was offered online with facilitated modeling:

This course is very well suited to online delivery because of the collaborative projects which do not require in-person meetings, discussion groups which are organized through Zoom, and using multimedia content for the projects. In fact, class time was used more effectively online than in-person, especially in the breakout rooms. The course models effective online instruction and has been very useful for me in changing my attitude towards online teaching while building skills. (TC6)

With respect to using online tools and resources, TCs said:

I learned to create online resources, making digital video games, and websites for the science curriculum. These are essential skills to use for my future teaching practices. (TC8)

We used a lot of different technologies in our assignments that increased my comfort level with them. I learned about other digital tools that could be used to enhance teaching and various pedagogical strategies that work online (like the case studies). (TC10)

On the other hand, TCs also responded to an open-ended question about online teaching skills needing ongoing improvement or reinforcement despite the material offered in the course. Analysis of TCs' responses identified four themes: enhancing student engagement and collaboration in online environments (10 out of 31 responses), online assessment (7 out of 31), synchronous teaching skills especially classroom management (6 out of 31), and more practice needed to master tools especially in real-world classroom scenarios (6 out of 31). They said:

I think ongoing assessment and participation needs improvement because I feel like it's difficult to get students to participate in discussion and I feel ongoing assessment is difficult because I don't get to see the students. I also think taking care of student mental health needs improvement because you aren't seeing them in person every day, so it makes it more difficult to recognize behaviour changes and check in with students meaningfully. (TC5)

I think just using them {the tools} practically with students and seeing what is effective with high school levels students would be beneficial. It's easy to talk about a resource being great but it actually being good in practice is different. (TC11)

Discussion and Conclusion

In this paper, we explored TCs' perceptions of online teaching as a teaching modality and the impact of the STEM course on their technological and pedagogical skills necessary for online teaching. First, with respect to pedagogical perceptions of online teaching, TCs showed more positive perceptions at the end of the course about the potential of online teaching environments to be creative, inclusive, collaborative, and reflective. These indicators are of specific importance as they relate to inquiry-based learning, student engagement, and inclusivity in STEM education which were noted to be challenging in online environments as reported by teachers during ERT (DeCoito & Estaiteyeh, 2022a). Yet, a few areas are noted for future exploration and further improvement, such as TCs' ability to address student differences online and the fact that they still prioritized content delivery over teaching methods. These findings parallel those of Han et al. (2017) and Aslan and Zhu (2017) who highlight the importance of attending to TCs' self-efficacy and perceptions toward technology; further they maintain that involving TCs in technology-centred experiences is essential to develop these perceptions. It is also worth noting that the observed impact of the course was consistent across both cohorts, despite higher levels of improvement in Cohort 2 compared to Cohort 1. This result may be due to relatively more negative initial perceptions of Cohort 1 as they experienced a more abrupt shift to online teaching at the time of conducting this study (academic year 2020-2021, the first year of the pandemic). This finding is in contradiction with Han et al.'s (2017) study in which TCs' initial beliefs minimally impacted the final outcomes.

Second, the results across both cohorts show a notable improvement in TCs' technological and pedagogical skills, as well as personal abilities utilizing innovative teaching and assessment strategies in online teaching. Teacher candidates shared how various elements of the course positively impacted their technological skills, such as using new software programs, improving use of familiar software programs, and organizing and presenting ideas online. Additional course elements mentioned by TCs include pedagogical skills necessary for online teaching, such as applying and utilizing technology in their teaching, and learning methods to increase student engagement and agency in online teaching settings. These skills are examples of the four general competency areas that are essential for digitally supported teaching in all subjects, according to the DiKoLAN framework (Von Kotzebue et al., 2021). Furthermore, with respect to examples of the three science-specific competency areas of the DiKoLAN framework and the four technology-related dimensions of the TPACK framework (TPACK, TPK, TCK, TK) (Koehler et al., 2013), TCs in both cohorts recorded higher scores in the post-survey compared to the pre-survey on items related to their familiarity with and competence using various online pedagogical strategies. These strategies include synchronous teaching, virtual labs, online simulations and digital games, online discussion tools, website creation for digital science resources, lab or simulation reports, and assessing content creation. However, two skills were noted as areas of improvement – developing competence in content creation software and utilizing online quizzes and tests for assessment.

Additionally, TCs highlighted that the course was particularly helpful as it modeled online teaching, offered specific online pedagogical skills, and provided teaching resources needed for online teaching. These findings are in accordance with other studies emphasizing the importance of focusing on pedagogical skills and content-specific training along with technological skills (Aslan & Zhu, 2017; Burns et al., 2020; Mishra & Koehler, 2006; Schubatzky et al., 2023), as well as the importance of involving TCs in designing digital STEM education resources (Burron & Pegg, 2021; Milner-Bolotin, 2019) – which was a large emphasis in this course. Some areas of improvement especially in promoting student engagement and collaboration in online environments, online assessments, online classroom management, and applying what they learned in real classrooms were still noted by TCs. These are also commonly reported challenges by teachers and TCs, as is evidenced in the literature (Ali & Nath, 2023; Alvi, 2023; Margaliot & Gorev, 2020).

In conclusion, these findings highlight the positive impact of the digitally enriched STEM curriculum and ICT training embedded in this course in order to develop and enhance TCs' technological and pedagogical skills and their perceptions of online teaching as a teaching modality. This research highlights the role of extended exposure to experiences that are designed to cultivate TCs' TPACK in teacher education, in which technological competencies are simultaneously refined along with pedagogical methodologies (Aslan & Zhu, 2017; Burns et al., 2020; Mishra & Koehler, 2006; Schubatzky et al., 2023). This conclusion confirms Karakaya's (2017) recommendation that improving TCs' technological knowledge should be part of science methods courses and not only educational technology courses, to ensure that TCs design lessons that integrate all TPACK components, as highlighted in this study.

Limitations and Implications

A major limitation in this study is reliance on self-reported assessment by TCs to reflect their development of pedagogical and technological skills. Although TCs' coursework was collected to analyze their skills in planning for online teaching, this analysis is beyond the scope of this paper as it will reflect their planning rather than facilitation of online classes. Future research can follow-up with TCs during their practicum or future classrooms to obtain a complete picture of their competence, challenges, and successes in online classes.

This research informs teacher educators and educational researchers, especially those in Canada, about the successes of teacher preparation programs and serves as a model for the development and implementation of high-quality online teaching training. This research provides insights for teachers, department leaders, policy makers, and teacher educators. Specifically, the research highlights the importance of providing adequate opportunities for TCs to cultivate and develop their TPACK framework, with a focus on STEM-contextualized technological and pedagogical skills, which seemed to be lacking during ERT. It aims to chart a path forward for developing essential skills and strategies that enable TCs and teachers to effectively engage in virtual classrooms, thereby ensuring rich, inclusive, and effective online learning experiences for all learners.

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Educational Robotics and Preservice Teachers: STEM Problem-Solving Skills and Self-Efficacy to Teach

Robotique éducative et formation initiale des enseignants : compétences en résolution de problèmes dans les STIM et auto-efficacité pour enseigner

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Abstract

Integrating STEM education within the elementary school science curriculum in Ontario, Canada, elevated the expectation for elementary preservice teachers to teach STEM skills such as problem-solving through coding. Research shows that educational robotics can promote STEM knowledge and skills. This mixed methods study investigates the effect of an educational robotics intervention on preservice teachers' STEM problem-solving skills and their self-efficacy to teach with educational robotics during the COVID-19 pandemic. Data sources included a pre- and post-questionnaire on problem-solving, a pre- and post- self-efficacy teaching questionnaire, a problem-solving worksheet, and transcripts of group interactions. Quantitative findings were statistically significant for preservice teachers' self-efficacy to teach with educational robotics (large effect size) and for problem-solving competencies (small effect size). Using a STEM problem-solving framework, two preservice teacher group interactions were analysed. Qualitative findings indicated that preservice teachers exhibited similar problem-solving processes as STEM experts, but preservice teachers' prior STEM knowledge limited the types of decisions considered at the problem-solving stages. The study provides an example of how preservice teachers' self-efficacy to teach with educational robotics was developed within a science education course and lends unique insights into the problem-solving processes these preservice teacher groups engaged in.

Keywords: educational robotics, preservice teachers, self-efficacy, STEM, problem-solving skills

Résumé

Avec l'intégration de l'enseignement des STIM dans le programme de sciences de l'école primaire en Ontario, au Canada, les futurs enseignants devront s'attendre à enseigner des compétences en lien avec la programmation informatique et la résolution de problèmes. La littérature scientifique montre que la robotique éducative peut favoriser l'acquisition de connaissances et de compétences dans le domaine des STIM. Cette étude à méthodes mixtes porte sur l'effet d'une intervention en robotique éducative sur les compétences en résolution de problèmes dans les STIM chez des enseignants en formation et sur leur auto-efficacité vis-à-vis de la robotique éducative pendant la pandémie de COVID-19. Les sources de données comprenaient des questionnaires sur les processus de résolution de problèmes et sur l'auto-efficacité relative à l'enseignement, une feuille de travail sur la résolution de problèmes et des transcriptions des interactions au sein du groupe. Les résultats quantitatifs étaient significatifs d'un point de vue statistique en ce qui concerne l'auto-efficacité des enseignants en formation initiale relativement à la robotique éducative (taille de l'effet forte) et leurs compétences en matière de résolution de problèmes (taille de l'effet faible). Les interactions de deux groupes d'enseignants en formation initiale ont été analysées selon un cadre de résolution de problèmes propre aux STIM. Les résultats qualitatifs indiquent que les processus de résolution de problèmes des enseignants en formation initiale sont similaires à ceux des experts en STIM, mais que les connaissances préalables de ces enseignants en STIM ont eu pour effet de limiter les types de décisions prises lors des étapes de résolution de problèmes. L'étude montre de quelle façon l'auto-efficacité de futurs enseignants vis-à-vis de la robotique éducative a évolué dans le cadre d'un cours de science et donne un aperçu unique des processus de résolution de problèmes que ces groupes d'enseignants en formation ont mis en œuvre.

Mots clés : auto-efficacité, compétence en résolution de problèmes, futurs enseignants, robotique éducative, STIM

Introduction

Rapid technological advancements have resulted in new and emerging STEM fields, like robotics engineering, which underline the need for skills such as critical thinking and complex problem-solving (OECD, 2023). Educational robotics (ER) can provide opportunities for school students to learn not only STEM concepts (Anwar et al., 2019; Park, 2015), but also ER can develop their confidence, interest, and participation in the STEM fields (Hudson et al., 2020; Miller et al., 2018) and help them develop problem-solving skills such as computational thinking (Zhang et al., 2021). Robotics programs have been commonly implemented by informal organisations, like science centres, as after-school programs (Nugent et al., 2012; Williams et al., 2008) and as robotics competitions (Chung et al., 2014; Karp & Maloney, 2013). Altin and Pedaste (2013) purport that to engage all learners and not just a small group of learners through robotics competitions, robotics should be included in the curriculum both "as a learning object and [as a] tool to learn other subjects" (p. 366). As a learning object, robotics is used to learn about how robots function and how to program them and the latter concepts are normally taught in technological subjects in secondary schools (Ontario Curriculum and Resources, 2009). Robotics as a tool can be used in many subjects to support learning—for example, learning the different principles of motion in physics (Altin & Pedaste, 2013).Traditionally, the use of ER in formal elementary education has been limited in scope with few teachers employing ER to support students' learning of programming knowledge and skills such as problem-solving and collaboration (Aurini et al., 2017; Darmawansah et al., 2023) or using it to develop confidence and interest in STEM subjects and careers (Hudson et al., 2020; Park, 2015). The informal integration of ER by teachers does not facilitate consistent and widespread use of robotics as an object and a tool in schools, and hence to reap the benefits there is a need for formal curricular integration of ER and coding in elementary schools for all students.

In Ontario, the revised version of the elementary Science and Technology curriculum emphasises the development of STEM process skills, specifically through scientific experimentation, scientific research and engineering design processes, and the development of global competencies including collaboration and digital literacy (Ontario Curriculum and Resources, 2022). With this formal curriculum emphasis, teachers are expected to know how to use technologies like ER and online programming applications (e.g., Scratch) in science and technology learning contexts. With a view to this curriculum revision, this paper reports on a study in a Science and Technology methods course in a Bachelor of Education program that occurred during the COVID-19 pandemic. The study investigated the effect of an ER activity on preservice teachers' (PTs') STEM problem-solving skills and their self-efficacy to teach with ER. Prior to COVID-19, PTs worked in groups of five or more due to the limited number of robotics kits available because of the high cost of purchasing these kits. However, face-to-face classes during the pandemic required stringent safety protocols be put in place. Hence, PTs, wearing masks, worked in smaller groups of twos and threes. These instructional experiences led to some changes to how the ER activity was implemented post-pandemic (discussed at the end of the paper). Results of this study can be used to inform the development of course activities for preservice science and technology methods courses and may support the design of new courses on ER and coding in teacher education. The results contribute to the literature on effective pedagogy for teaching STEM problem-solving skills and provide insights on how problem-solving skills were developed by elementary PTs during ER activities.

Literature Review

Since the study investigated how ER promoted *self-efficacy* and *problem-solving* during preservice teacher participation in an *ER* activity, literature related to the three constructs (italicised) and in relation to PTs are reviewed.

Educational Robotics

Educational robotics has been incorporated in school learning in various ways over the last 20 years, propelled by the development of robotics kits, like LEGO® Mindstorms, for the masses (Anwar et al., 2019). Robotics is a learning tool that lends itself to experiential and student-centred approaches because it is a concrete manipulative that children interact with and explore while solving real-world problems and constructing knowledge (Eguchi, 2021; Glezou, 2021). In K-12 learning environments, ER use includes robotics kits, programming software, and computers being used as hands-on learning tools to support problem-solving, critical thinking, collaboration, and learning of abstract concepts and ideas (Eguchi, 2021). Studies show that ER activities provide opportunities for students to apply knowledge and skills from many of the STEM disciplines as they problem-solve (Ching et al., 2019; Siverling et al., 2018) and promote the development of collaboration and problem-solving skills (Nemiro, 2021; Taylor & Baek, 2018). Educational robotics is therefore suitable for developing 21st century competencies such as critical thinking and innovation (cognitive competencies), communication and collaboration (interpersonal competencies), and initiative and metacognition (intrapersonal competencies), as well as STEM literacy (National Research Council, 2014). According to Bybee (2013), STEM literacy includes asking questions, solving problems, explaining phenomena, and understanding how to use inquiry and design.

Robotics-based activities are particularly suited to developing scientific inquiry and engineering design skills such as posing questions and constructing explanations (scientific inquiry skills) and defining problems and constructing prototypes of products (engineering design skills; National Research Council, 2012). LEGO® Robotics in middle schools has been used to develop and reinforce math concepts, the scientific and engineering design process, programming, problem-solving, and teamwork (Benitti, 2012). With respect to engineering design, when students construct and program robots, they define the engineering problem (e.g., how does the robot work to solve the problem?), propose the solution to the problem (e.g., how to build the robot), and consider optimisation (e.g., how to improve the efficiency of the robot to complete the task) (Ziaeefard et al., 2017). Research suggests that ER supports student learning of concepts and skills in the STEM areas in both formal and after-school or extracurricular contexts (Anwar et al., 2019; Williams et al., 2008). However, there were mixed findings reported about the impacts of robotics on science and math attitudes and learning. For example, in a mixed methods study, Ching et al. (2019) found, among 18 Grade 4–6 students participating in a STEM, project-based learning robotics curriculum conducted over eight weeks in an after-school program, no statistically significant improvement in attitudes towards science, engineering, and technology but results were significant for mathematics attitudes. In another mixed methods study (Sáez-López et al., 2019) with 93 middle school students doing Scratch coding integrated into a math and science unit, results showed improved comprehension of math and programming concepts but not for science concepts. Some of these mixed results may be due to challenges students experienced such as complicated designs, missing robot parts, visuals and written guides that were hard to follow (Ching et al., 2019; Kopcha et al., 2017), and challenges linked to teacher training (Sáez-López et al., 2019), especially teachers' lack of knowledge and experience with coding and programming (Kopcha et al., 2017). Other challenges reported by teachers were that science standards were not emphasised as much as math and engineering in the robotics activities, with teachers calling for stronger connections made to science curriculum standards (Kopcha et al., 2017). The National Research Council (2014) also noted that the success of STEM learning "depends on the approach to integration and the kinds of supports that are embedded in the experience and provided through instruction" (p. 3). Therefore, besides knowledge of pedagogical approaches such as engineering design, teachers need to know how to incorporate strategies like peer collaboration and scaffolds to make STEM connections explicit, as these strategies help students succeed at challenging STEM tasks (National Research Council, 2014). This current study also provides insights into the instructional scaffolds used to support PTs to learn how to develop STEM skills by means of ER in the classroom.

Preservice Teacher Self-Efficacy to Teach and Educational Robotics

Teacher self-efficacy or confidence in their ability to plan and implement learning experiences is an important factor that contributes to effective teaching (Darling-Hammond & Baratz-Snowden, 2007;

Nolan & Molla, 2017). Self-efficacy beliefs play a significant role in how people are motivated, make choices, and behave in specific settings. Self-efficacy, as explained by Bandura (1994), indicates a person's belief in his or her capability to carry out actions or complete a task to produce specific outcomes and it includes a judgment regarding how well he or she can perform the task or action and his or her confidence in having the skills to do the task or action. Four ways have been suggested to develop a person's self-efficacy: 1) mastery experiences which involve direct experience with and successful completion of the action or task; 2) vicarious experiences through observing social role models successfully complete a task; 3) social persuasion through positive verbal feedback; and 4) emotional and physiological states that are managed to reduce stress reactions (Bandura, 1994). Studies on how these strategies affect teachers show that some strategies are more effective than others at developing teacher self-efficacy. For example, while vicarious experiences such as modeling (e.g., observing another person teach) and enactive mastery (that is, perceived successes in prior teaching) enhance self-efficacy among elementary science teachers, it was cognitive mastery of pedagogical content knowledge and verbal persuasion through in-situ feedback that were more effective (Palmer, 2011). Velthuis et al. (2014) also reported that it was the practical experiences of PTs teaching science to students in the classroom that most impacted their self-efficacy beliefs about teaching science. The role played by subject-matter knowledge on teacher self-efficacy in general suggests that there was a relationship between subject-matter knowledge and self-efficacy (Rohaan et al., 2012).

With respect to technology integration, studies (e.g., Lemon & Garvis, 2016) show that many PTs do not feel confident about integrating technology in general into teaching practice. A few studies on PTs' self-efficacy to teach with robotics in instructional technology courses (Fegely & Tang, 2022; Kucuk & Sisman, 2018; Piedade et al., 2020) reported that PTs were motivated to teach programming to students after the ER course experiences. Findings by Piedade et al. (2020) suggested that collaborative, problem-solving activities such as planning, designing, and implementing scenarios with robots contributed to PTs' confidence to teach with robotics. Some studies have explored how ER can be integrated in science education courses to develop PT self-efficacy to teach programming and develop computational thinking skills (Jaipal-Jamani & Angeli, 2017; Kaya et al., 2017; Schina et al., 2021). Schina et al. (2021) reported on PTs in the Spanish context and the study by Kaya et al. (2017) was in a US context. The current study adds to the literature on PT self-efficacy to teach with robotics in elementary science in a Canadian context.

STEM Problem-Solving

With recent curricular emphasis on learning STEM skills to deepen the understanding of fundamental concepts such as automation (new addition) in the Ontario elementary Science and Technology curriculum (Ontario Curriculum and Resources, 2022), it is an expectation that elementary school students engage in instructional activities that develop STEM problem-solving processes such as inquiry, engineering design, and computational ways of thinking (e.g., leaning how coding controls automated systems). The OECD (2015) also emphasised collaboration as an important aspect of the problem-solving process whereby two or more persons "attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills and efforts to reach that solution" (p. 6). While some problem-solving skills may be unique to individual STEM disciplines, for example, constructing prototypes in engineering, Price et al. (2021) found that scientist and engineer experts in STEM fields including biology, medicine, physics, chemistry, engineering, and computer science made common decisions during problem-solving. The authors therefore proposed a STEM problem-solving model consisting of six general categories: selection and goals of the problem; frame the problem; plan the process for solving; interpret information and choose solutions; reflect; and implications and communication of results. They also detailed a number of decisions made in each category (Table 1).

Table 1

Decisions Made by STEM Experts at Each Problem-Solving Category (Price et al., 2021)

Problem-solving category	Decisions made
Selection and goals of the problem	1. What is important in the field? 2. Opportunity fits solver's expertise? 3. Goals, criteria, constraints? What are goals, design criteria, requirements of problem or the solution; scope of the problem; constraints on solution; and criteria to evaluate solution?
Frame the problem	1. What are important features, concepts, information, representations of problem? 2. What predictive framework to use? 3. How to narrow down the problem through questions and hypotheses? 4. What are related problems or work seen before (review literature or reflecting on prior experience)? 5. What are potential solutions (identifying key features and fitting some criteria for solution)? 6. Is problem solvable in view of constraints and risks?
Plan the process for solving	1. How to simplify the problem and test the approximations against established criteria? 2. How to decompose the problem into sub-problems or smaller steps? 3. Identify areas of uncertainty and difficulty. 4. What information is needed to solve the problem to test and distinguish potential solutions? 5. What to prioritise? Constraints, cost, resources, etc. 6. How to obtain information including specific plan of getting information and how to carry out problem-solving plan such as designing, conducting experiments, etc. What are other possible alternative outcomes?
Interpret information and choose solution(s)	1. What calculations and data analysis are needed? 2. How to represent and organise information?

Problem-solving category	Decisions made
	3. How believable is information (validity and reliability and biases)? 4. How does new information from experiments or calculations compare to expected results? 5. How to follow up on anomalies? 6. What are appropriate conclusions based on data? 7. What is the best solution?
Reflect	1. Are assumptions and simplifications still appropriate? 2. Is more information needed and, if so, what? 3. How well is the approach working and are modifications needed? 4. How good are the potential solutions? Can test failing options or see if it meets goals/criteria?
Implications and communication of results	1. What are broader implications of results? 2. Who is the audience to communicate the work? 3. What is the best way to present the work?

Since ER incorporates the application of knowledge and processes from the STEM disciplines during problem-solving (Ching et al., 2019; Siverling et al., 2018), the STEM problem-solving model described in Table 1 was used to analyse PTs' development of problem-solving skills during the ER activity.

Methodology and Procedures

A mixed methods study (Creswell & Plano Clark, 2017) was conducted to investigate the following questions:

1. How does the ER intervention influence PTs' development of STEM problem-solving skills during the ER activity?
2. How does participation in the ER activity influence PTs' self-efficacy to teach with ER?
3. What types of problem-solving processes did PTs engage in during the ER activity?

A quasi-experimental, one-group, pre- post-test design was implemented to determine research questions 1 and 2 as it was not possible to randomly assign participants to groups (Privitera & Ahlgrim-Delzell, 2018). Concurrently, to provide a rich, in-depth description of the problem-solving process experienced during the robotics tasks, selected group interactions were observed and audiotaped.

Participants and Sampling

The study participants were PTs in the first year of a Bachelor of Education program being certified to teach junior/intermediate science for Grades 4–10. The majority of PT participants were non-science, undergraduate majors from three class sections of a Science and Technology methods course. The robotics activities were implemented as part of the course curriculum. Since PTs were in pre-assigned sections of courses, the study sample was a convenience sample. Ethics consent was obtained from the University and, to minimise conflict of interest, a research assistant invited PTs to participate in the study. Participation in the research components was voluntary and did not contribute to course grades. A total of 57 PTs provided their consent. However, the total number of participants who completed both pre- and post-data instruments was 36. For the qualitative analysis, two groups consisting of two and three PT participants, respectively, were selected on the audibility and succinctness of the transcripts to showcase the similarities and differences in the problem-solving processes and having a complete set of data for triangulation purposes.

Study Context and Robotics Activities

The robotics activities were facilitated by the author in all three class sections during a 3-hour class session in week 9 of the 12-week course during Winter 2022. The author was the instructor for one section only. Pre-instruments were completed at the beginning of the ER activity session and post-instruments were completed two weeks after the ER activity session. During the ER session, data were collected by the research assistant. In the classes prior to and after the robotics activity, PTs were exposed to topics that included the science and technology curriculum structure and content, unit planning approaches, assessments in science, nature of science, environmental education, cross-curricular language and Indigenous connections, and hands-on workshops such as on electrical circuits. Preservice teachers also conducted science demonstrations to teach a concept, however they did not experience any type of problem-solving activities involving robotics and coding. As well, PTs were asked about their prior knowledge of robotics for use in teaching and learning on a pre-questionnaire; 17% (6 PTs) felt they had sufficient prior knowledge of ER. The goals for this robotics activity were consistent with the expectations of the Ontario Science and Technology curriculum which was to promote the development of STEM skills, particularly coding, problem-solving, and teamwork, and to deepen understanding of how coding controlled automated systems. Preservice teachers used LEGO® EV3 Mindstorms robotics kits and downloaded the coding software onto their personal computers. During this process, some PTs did experience technical issues. Specific STEM skills addressed in the ER activity included creating a model of a robot, learning to program basic moves and turns for the robot, and then solving a real-world problem with the robot; specifically, PTs constructed a model of a vehicle base, programmed the base/car to move in a straight line and make turns, and then they problem-solved how to park the car autonomously. Preservice teachers worked in dyads or groups of three and the activity was scaffolded with a worksheet that guided PTs to learn how to code, from simple to more complex programming steps.

Data Collection Methods

Quantitative data collection methods included:

- a pre–post, 20 item questionnaire on STEM problem-solving skills adapted from the validated questionnaire (see https://oerl.sri.com/instruments/ITEST/interviews/studsurv/instrNew2.html). The items were rated on a 5-point Likert scale from strongly disagree to strongly agree.

- a pre–post, self-efficacy to teach questionnaire.

Qualitative data included:

- a worksheet with scaffolded programming instructions (simple to complex coding).
- audio recordings of PT group interactions.
- video and photographs of programs and robot outputs.

Data Analysis

Data analysis occurred after final grades for the PTs were submitted. All questionnaires were analysed with SPSS 27. Normality tests were conducted at the 95% confidence interval for n=36 and were normal. Problem-solving skills were measured by summing five items (5, 6, 8, 9, and 10) from the STEM questionnaire. Then Cronbach's alpha was calculated to show the degree of internal consistency for the items. The Cronbach's alpha obtained for the summed scores of five items was pre = .790, post = .816, indicating acceptable values for reliability (George & Mallery, 2003). The self-efficacy measure consisted of four items that rated confidence on a scale from 0 to 100 (from not confident to completely confident). Items were (A) I feel confident that I have the skills necessary to use robotics for classroom instruction; (B) I feel confident that I can engage my students to participate in robotics-based projects; (C) I feel confident that I can help students when they have difficulty with robotics; and (D) I feel confident about teaching students science using LEGO® robotics. Cronbach's alpha values obtained for the four items were pre = .927 and post = .938, indicating that the instrument reliability was good. Paired samples t-tests were conducted and effect sizes calculated using Cohen's d where $d = 0.2$ (small effect), $d = 0.5$ (medium effect), and $d = 0.8$ (large effect) as suggested by Cohen (1988).

Qualitative analysis involved using the problem-solving framework to code lines (Table 1). A preliminary reading of the group transcripts reflected similar processes within group interactions. Two groups were selected based on audibility and succinctness of the transcripts to showcase the similarities and differences in PT problem-solving processes.

Results

Quantitative: Problem-Solving Skills

A paired samples t-test for problem-solving skills showed that there was a significant difference in problem-solving skills between pre- and post-test, $M = .64$; SD = 1.93; $t(35) = 2.085$; $p = .044$ at the 95% confidence level with a small effect size, Cohen's $d = 0.348$. These findings suggest that PT participation in the problem-solving ER activities resulted in small changes to problem-solving competencies such as using a step-by-step process to solve problems.

Quantitative: Self-efficacy to Teach with ER

Results indicated that participation in the ER problem-solving activity increased PTs' self-efficacy, M =11; SD = 8.59; $t(36) = 7.693$; $p < .001$ with a large effect size, Cohen's $d = 1.28$. These results suggest that the ER intervention did result in large practical gains in self-efficacy among this group.

Qualitative: Problem-Solving Processes During Group Interactions with ER

Two cases of selected group interaction excerpts are presented in Table 2 and Table 3, respectively, to illustrate a sample of the decisions that PTs made during the problem-solving task of creating a program to parallel park a vehicle autonomously. A comparison of the two group interactions in terms of the problem-solving categories and decisions revealed some common decisions (Table 1). Both groups *framed the problem* in a similar way (Table 2, L 1–2; Table 3, L 1–2) by relating or situating the problem in a real-life parking situation and reflecting on prior, everyday experiences of parallel parking. Both groups *collaborated with their peers* to come up with a plan and solution; however, the steps involved in *planning the process for solving* and *interpreting of information and choosing solutions* were sequenced differently by the two groups. For example, Group 1 began by *testing their initial solution* through *tinkering through trial and error* (Table 2, L 6), whereas Group 2 proposed the *initial plan by decomposing the problem into smaller steps* and *identified important criteria* such as *the mathematical parameters of the problem* (Table 3, L 4–6) before testing. Both groups did conduct testing and troubleshooting through *trial and error* (Table 2, L6; Table 3, L40) but the number of iterations varied in the groups, resulting in different insights gained. Group 2 did multiple tests and retests (Table 3, L 46–49) and realised that it would be necessary to tell their students to mark where they were starting the parking to be able to repeat the movement as coded (L 50). Both groups *reflected on how well the solution worked* (Table 2, L 65–68; Table 3, L 41–46) and *communicated their solutions* (Table 2, L 69–70; Table 3, L 51–52) through visual code on a computer and demonstration of parking.

Table 2

Selected Excerpts Illustrating Problem-Solving Decisions of Group 1: Speaker 1 (female) and Speaker 2 (male)

Line	Speaker	Preservice teacher's group interactions	Problem-solving decisions
L1	Speaker 2	Yes. Okay. So realistically, when you reverse park in real life, it's like a 45 degree kind of...	Relating to a real-life situation
L2	Speaker 1	: Yeah, I always go like... yeah.	Reflecting on prior everyday experience
L3	Speaker 2	So I feel like if we maybe start, try with 45 degrees. So we can do move... right 45 degrees. Does that make sense?	Proposing a tentative solution to try out Seeking consensus
L4	Speaker 1	I feel that's going to turn it.	
L5	Speaker 2	I know. I don't know, I have no idea.	

Line	Speaker	Preservice teacher's group interactions	Problem-solving decisions
L6	Speaker 2	Okay. We've got to figure out which way it's going to move. Let's just make it move. [run program] That was close.	Tinkering through trial and error
L7	Speaker 1	Okay. No, then we need to [inaudible 00:02:28] straight in.	Reflecting on solution
L8	Speaker 2	Come up and then go back in?	
L9	Speaker 1	Yeah.	
L10	Speaker 2	Back into the spot. So we want to go like this, and then forward-	Decomposing the problem into smaller steps by reflecting on prior experience
L11	Speaker 1	Forward, and then back.	
L12	Speaker 2	And then straight back-	
L13	Speaker 1	Yeah.	
L14	Speaker 2	... like a car. That'd be cool. Oh... So we have it rotating right and then we're going to change this then.	
L15	Speaker 1	Backward.	
L16	Speaker 2	Yeah. And then we're gonna add…	
L17	Speaker 1	Forward. And so now the...	
L18–L64		Omitted	Trial and error
L65	Speaker 2	That's pretty good. That was sweet. I won't lie. So it still went a bit much. 20? Where did you put it, because it was in a good spot? [test the new value] Right there? No. That was so good. I'm impressed. Right here?	Reflecting on how well the solution worked
L66	Speaker 1	Yeah.	
L67	Speaker 2	Oh my god-	
L68	Speaker 1	That was a perfect one. That was so good.	

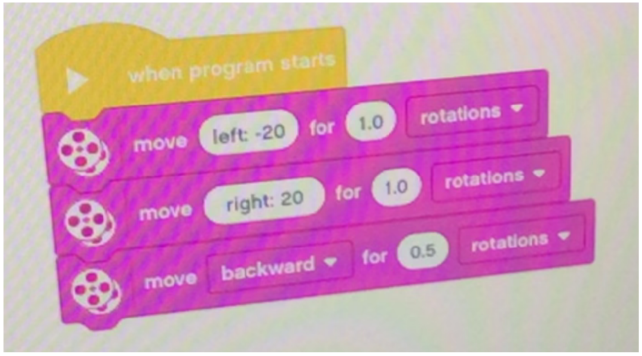
Line	Speaker	Preservice teacher's group interactions	Problem-solving decisions
L69			Communicating results on the computer as a code
L70		 GA-1 parallel parking.MOV [1]	Demonstrating the parallel parking

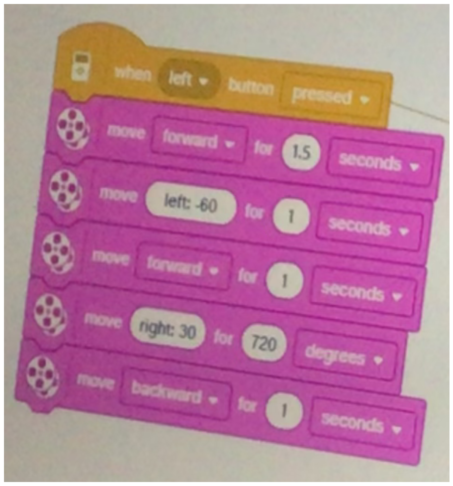
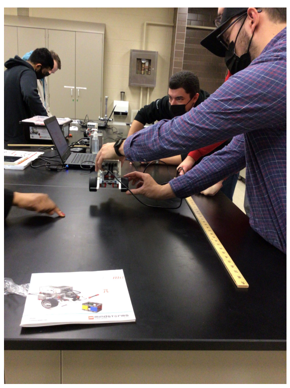
Table 3

Selected Excerpts Illustrating Problem-Solving Decisions for Group 2: Three Male Speakers

Line	Speaker	Group interactions	Problem-solving decisions
L1	Speaker 2	So are we going to pretend that this is like a road. Do you guys want to put like fake pylons or something.	Relating to a real-life situation
L2	Speaker 1	Just so we have a barrier for reference. When I think about parallel parking, you come up. ….	Reflecting on prior everyday experiences
L3	Speaker 2	Yeah.	
L4	Speaker 1	Maybe we'll start back here. We'll pull up past the spot and then we'll back into it, okay? So first let's find out how far forward we have to go. So, we know that if we move forward for one rotation it goes forward for 17.5 centimeters roughly	Decomposing the problem, identifying important criteria or features e.g., math to find solutions
L5	Speaker 3	Inches.	
L6	Speaker 1	Let's do centimeters. So this looks like ….	
L7	Speaker 2	Wait, that doesn't add up.	
L8	Speaker 1	What doesn't add up?	

[1] https://www.youtube.com/shorts/CXkRD7c5NTY

Line	Speaker	Group interactions	Problem-solving decisions
L9	Speaker 2	How would we get 84 centimeters with four and a half rotations?	Reflecting on proposed solution and identifying problems with the math
L10–39 omitted			
L40	Speaker 1	Yeah, because instead of one rotation, let's try 1.2. [test]	Testing by trial and error
L41	Speaker 3	There you go.	Reflecting on how well the solution worked
L42	Speaker 1	That's pretty good.	
L43	Speaker 2	Yeah.	
L44	Speaker 1	I don't know if we're going to get any-	
L45	Speaker 2	More perfect.	
L46	Speaker 1	More perfect than that. Maybe let's try back just a little bit further, 1.5. We'll see if that makes any difference.	Reflecting on how well the solution worked Testing and retesting Collaboration and input from members
L47	Speaker 2	That's perfect.	Testing and retesting Collaboration and input from members
L48	Speaker 3	I mean it kind of hit the curb a bit but so do I when I parallel park.	
L49	Speaker 1	I think that's perfect. I think that's perfect, let's do that one more time. [test program] Oh, that's still wide. I think I started a little more in than the last time. We should have really marked this, somehow where we started.	Testing and retesting Collaboration and input from members Reflecting on how well the solution worked
L50		Yeah, lesson learned. We'll make sure to tell students that mark where you start on there. We have it down pat. It just depends on where you start.	Realising how to scaffold the activity for their own students

Line	Speaker	Group interactions	Problem-solving decisions
L51			Communicating results on the computer as a code
L52			Demonstrating the solution

Discussion

This mixed methods study examined the effect of an ER intervention on PTs' self-efficacy to teach with ER and on their STEM problem-solving skills. The study also provided insights into the decisions that PTs made as they used ER to problem-solve. The quantitative results showed that participation in this ER activity, scaffolded with a worksheet that incrementally introduced students to visual coding blocks from simple to more complex tasks, was effective (large effect size) at developing this group of PTs' self-efficacy to teach with ER. Preservice teachers first created codes to make a driving base execute simple movements and turns and then solved more complex challenges – moving a distance in a straight line and then parallel parking. While a limitation of this study is that it is based on a short intervention, other studies have shown that scaffolded ER activities over a short period and structured modules do enhance PT confidence to integrate ER in teaching (Jaipal-Jamani & Angeli, 2017; Schina et al., 2021). In the current study, learning to teach with ER was scaffolded through instructor modeling scaffolding strategies (e.g., guiding the learning with a structured worksheet and providing hands-on experiences with ER). Such strategies have been shown to provide pedagogical insights to enhance teacher self-efficacy to teach (Tschannen-Moran & Hoy, 2007).

With respect to PT problem-solving competencies, the quantitative results were statistically significant with a small effect size, suggesting ER had a small practical impact. The latter result could be due to the short duration of the ER activities which were conducted over a 3-hour class session. For PTs in the current study, participation in more problem-solving ER activities over time may have resulted in a larger effect size for problem-solving skills. Interestingly, in another study that explored the effect of ER on problem-solving skills of middle school students, Zhang and Zhu (2022) reported that the effect of ER on problem-solving skills was smaller when compared to creativity skills and when compared to problem-solving among primary/junior students. These authors suggest that the smaller effect size for middle school students may be related to students having less exposure to hands-on experiences which are more common in the lower grades.

Nevertheless, the qualitative analysis of PT interactions during the problem-solving challenge of parallel parking yielded insightful results. The findings provide insights into the collaborative problem-solving processes as experienced by a group of junior/intermediate PTs in a particular Canadian context. The analysis showed that these PT groups followed the stages of problem-solving similar to those of STEM experts as proposed by Price et al. (2021). Preservice teachers began with framing the problem, engaged in planning, interpreted information and chose a solution, and reflected on and then communicated the results. However, unlike STEM experts, the decisions made at each problem-solving stage were limited to their personal and practical, everyday knowledge, with one group referencing STEM knowledge. Group 1 relied mainly on prior, everyday experiences of parallel parking to propose a plan and then learned how to decompose the problem into small steps after trial and error. Group 2 also used prior, everyday knowledge of parallel parking but drew on prior mathematics knowledge. They used mathematics criteria to decompose the problem during the planning phase and then tested the plan, followed by multiple tests and revisions. Multiple revisions by this group enabled them to gain pedagogical insights – their experiences as learners doing the activity made them realise that as teachers they needed to let students know to tape or mark the spot where the motion of the car began to be able to repeat the motion as coded. A comparison of the planning by the two groups suggests that everyday, practical knowledge and some STEM knowledge of novice problem-solvers (in this study mathematics knowledge) affected the sequencing and the types of problem-solving decisions made. Research by Tan et al. (2023) showed similar results with Grade 8 students, who also used practical knowledge to justify decisions more than they used disciplinary STEM concepts to explain decisions. The latter results suggest that to enhance novices' use of STEM knowledge in the framing and planning stages of problem-solving so they can identify salient STEM criteria, novices should possess some pre-requisite knowledge of the problem context and STEM knowledge, such as mathematics skills and distance–speed relationships, before engaging in the ER activity. In the current study, the problem-solving context (driving) was familiar to the PTs and scaffolding for the mathematics knowledge was provided as hints on the worksheet. However, it was up to the PTs to read the worksheet and figure out other salient features–i.e., how speed affected distance–to the problem. With elementary school students, the teacher may need to provide more overt guidance such as a review of relevant STEM concepts pertinent to the problem or highlighting important features on the worksheet. Another finding of the current study is that peer interactions and feedback within the two groups promoted experimentation and reflection on problem solutions. Research shows that peer groups allow novice teachers like PTs to learn, experiment, and reflect on practice with feedback from their peers, which strengthens their ability to implement new pedagogies (Darling-Hammond & Baratz-Snowden, 2007). Another insight gained through analysis of the transcripts and observation of small group interactions during the study, was that the smaller groups, created to meet COVID-19 safety protocols, enabled all members to engage in the problem-solving process and minimised students in observer roles. The pedagogical issue of insufficient ER kits, which normally results in large group sizes, and the technical issues encountered when PTs downloaded software, can be addressed by using ER kits that offer free, online coding platforms with virtual ER simulations. Hence, a change recommended for the implementation of the ER activity post-COVID to continue to work in smaller groups (three or less) is for some PTs to work with physical ER kits (e.g., VEX robotics) while other groups learn coding with a simulated robot online. Examples of free or subscription based online, virtual, coding platforms are Virtual Robot Simulator and Imagine Robotify.

Limitations of the study include that findings cannot be generalised to all elementary PT populations due to the small sample and short duration of the intervention. However, some insights such as how to scaffold ER activities to support STEM problem-solving in groups may be applicable to similar teacher education contexts. The findings are also not applicable to secondary science PTs who have more STEM background knowledge and therefore may exhibit different decisions at the problem-solving stages. Another limitation of the study, similar to the Schina et al. (2021) study, is that PTs were not observed in the field to follow up on whether they implemented ER in classrooms. This was due to challenges encountered: PTs do their practice teaching in different elementary schools in year 2 of the program and they often do not teach science; many schools do not have ER kits so PTs may not be able to implement ER in schools; and it is challenging or a lengthy process to obtain ethics clearance to conduct research in schools. A suggestion for future research could therefore be to administer an online survey to PT participants at the end of the teacher education program to obtain data on their use of ER during the practicum. In this way, information on the frequency of ER use and for what purposes ER is used in schools can be obtained. Such information is useful to inform revisions to teacher education courses and promote collaborative professional learning programs with school boards to increase PT and teacher ER use for developing STEM knowledge and skills. It should be noted that the effect of gender and cultural differences was beyond the scope of the study.

Conclusion

Using a mixed methods, quasi-experimental design, this study implemented during the COVID-19 pandemic, explored the effect of an ER intervention activity on middle school PTs' self-efficacy to teach with ER and develop STEM problem-solving skills. The findings suggest that participation in scaffolded ER activities, in small groups, is a promising strategy to improve middle school PTs' self-confidence to teach with ER and develop their STEM problem-solving skills. A practical suggestion for implementing ER activities post-COVID, which is increasingly characterised by online and hybrid learning environments, is to use virtual ER simulations, which also addresses the issue of not having access to physical ER kits. Finally, this study makes a methodological contribution by illustrating how a STEM problem-solving framework can be used to analyse group discourse to identify the problem-solving decisions/processes made during an ER activity.

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Déroulement et retombées de projets bricoleur (*maker*) à l'élémentaire : une revue de la portée

The Design and Implementation of Maker Projects in Elementary Schools: A Scoping Review

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Résumé

Le mouvement bricoleur (maker) connaît une popularité croissante dans les écoles du monde entier, mais la recherche, en particulier en français, est encore à un stade émergent. Cet article propose une revue de la portée des projets bricoleur dans les salles de classe de la 4e à la 8e année (secondaire 2) à l'échelle internationale, qui vise à analyser leurs descriptions, le déroulement, les outils utilisés et les retombées sur les élèves et le personnel enseignant. Sur 1 900 études initialement recensées et 68 articles scientifiques retenus aux fins d'analyse, l'étude définit trois phases principales des projets bricoleur : 1) l'inspiration et la préparation, 2) la mise en œuvre et la réalisation, et 3) la présentation et la recontextualisation, et elle souligne l'équilibre entre les outils numériques et physiques dans les études du corpus. Elle examine aussi les retombées sur les élèves à travers les dimensions affectives, sociales, disciplinaires et métacognitives, ainsi que sur le personnel en ce qui a trait aux dimensions pédagogiques, affectives et sociales. Des exemples de projets bricoleur disciplinaires, interdisciplinaires et transdisciplinaires sont présentés, illustrant l'ampleur et le potentiel du mouvement bricoleur. Ces résultats sont essentiels pour renforcer la formation enseignante, en s'appuyant sur les recommandations issues de recherches récentes, afin de favoriser la conception et l'intégration de projets bricoleur dans les salles de classe.

Mots clés : bricoleur, formation enseignante, maker, revue de la portée, technologies éducatives

Abstract

The rise in popularity of the maker movement in schools is evident around the globe, yet research, particularly in French, is still in early stages. This article provides a scoping review of maker projects in grades four through eight classrooms in elementary schools from around the globe, aiming to uncover their implementation, materials used, and outcomes on students and teachers. From 1900 initial studies, 68 scientific articles were analyzed. This article outlines the three stages of maker projects: 1) inspiration and preparation, 2) implementation and realization, and 3) presentation and recontextualization, while highlighting an equal mix of digital and physical tools within the selected papers. It also discusses the impact on students across affective, social, disciplinary, and metacognitive dimensions, as well as on teachers, including pedagogical, affective, and social outcomes. Examples of disciplinary, interdisciplinary, and transdisciplinary maker projects are highlighted, showcasing the broad scope and potential of maker education. These findings are essential for strengthening teacher education with research-informed best practices for designing and integrating maker projects in classrooms.

Keywords: digital technologies, maker, maker education, scoping review, teacher education

Introduction

Les projets maker, ou ce que nous préférons nommer de projets bricoleur, impliquant la création d'artefacts numériques et/ou physiques par les élèves, gagnent en popularité dans les écoles élémentaires mondialement, y compris au Canada. Centrés sur la conception et la réalisation de projets individuels ou collaboratifs, ces projets se servent souvent d'outils considérés emblématiques du mouvement bricoleur, tels que les imprimantes 3D, les logiciels de codage et les découpeuses laser ou d'outils physiques tels que les objets recyclés, de matériaux électroniques ou des *e-textiles* (Rouse & Gillespie Rouse, 2022). L'implication des élèves dans ces projets peut enrichir le développement de littératies traditionnelles, disciplinaires et numériques (Becker & Jacobsen, 2021; Hagerman, 2017; Hagerman et al., 2022) et cultiver l'innovation, la curiosité et une approche créative de résolution de problèmes (Chu et al., 2017; Hughes, 2017). Ces atouts constituent la base de la conviction soutenue par des revues de recherches récentes que les projets bricoleur peuvent influencer positivement l'apprentissage des élèves (Rouse & Gillespie Rouse, 2022; Schad & Jones, 2020). Pourtant, les programmes de formation à l'enseignement commencent à peine à documenter l'intégration d'initiatives liées au mouvement, aux outils, pratiques et pédagogies bricoleur dans leurs programmes et davantage de recherches sont nécessaires sur ce sujet (Caratachea et al., 2023; Rodriguez et al., 2018; Schad & Jones, 2020). Qui plus est, le passage à l'enseignement en ligne ou hybride adopté à travers le monde en 2020 a restreint les occasions pour le personnel de développer ou de renforcer leurs pédagogies centrées sur le bricolage (Becker & Jacobsen, 2021).

Les recherches systématiques sur le déroulement et les retombées de ces projets bricoleur, qui pourraient notamment orienter leur intégration à la formation enseignante, restent beaucoup trop limitées. Dans leur revue, Vossoughi et Bevan (2014) se sont concentrés sur les activités maker en contexte extrascolaire avec une attention particulière aux domaines STIM. Papavlasopoulou et al. (2017)

ont examiné des recherches empiriques dans les contextes scolaires, extrascolaires et postsecondaires en mettant l'accent sur les technologies, les disciplines et les méthodes d'évaluation, mais seules les études jusqu'en 2015 ont été incluses. Les revues de Schad et Jones (2020) et de Rouse et Gillespie Rouse (2022) touchent les études sur le bricolage dans les classes de la maternelle à la 12^{e} année (1re année du cégep), mais les pratiques pédagogiques et exemples de projets basés sur la recherche pour le personnel enseignant y sont absents. Par ailleurs, il est important de noter qu'à ce jour, aucune étude n'a explicitement recensé le déroulement des activités bricoleur. Pourtant, il est essentiel de mieux comprendre comment créer et mettre en œuvre ces projets bricoleur, en s'appuyant sur des recommandations issues de la recherche, pour éviter le risque d'activités simples et répétitives qui limitent l'autonomie, les erreurs, la créativité, voire l'apprentissage, des élèves (Davidson & Price, 2018). Dans cette optique, cette revue de la portée a pour objectif d'effectuer une étude systématique de la littérature scientifique existante sur les projets bricoleur dans les écoles élémentaires, plus précisément avec des enfants âgés de 9 à 14 ans, dans le monde entier. Cette revue se concentre sur cette tranche d'âge car elle s'inscrit dans le cadre d'une étude canadienne plus large, financée par la fondation LEGO, portant sur l'apprentissage ludique *via* le numérique, le plein air et le bricolage physique et numérique (Hollweck et al., 2023). L'objectif de cette revue de la portée est de fournir une vue plus complète sur les possibilités pédagogiques de ces projets bricoleur en offrant une description exhaustive de leur déroulement, des outils privilégiés et de leurs retombées. Nous visons ainsi à répondre aux questions de recherche suivantes : d'après la littérature scientifique, comment les projets bricoleur physiques et numériques sont-ils décrits en contextes éducatifs auprès d'élèves de la 4^{e} à la 8^{e} année? Quels types de projets bricoleur ont été recensés et quelles sont les retombées rapportées?

Malgré une augmentation du nombre d'études sur le mouvement bricoleur en éducation, la recherche scientifique publiée en français sur ce sujet reste insuffisante, ce qui constitue une lacune problématique pour les communautés de recherche et le personnel enseignant francophones. La rédaction de cet article en français contribue à combler cette lacune, bien que notre corpus soit constitué d'articles anglophones.

Ancrages théoriques

Constructionnisme

La majorité des chercheurs situent les projets bricoleur, qu'ils soient physiques ou numériques, du mouvement bricoleur dans un cadre constructionniste (Bevan, 2017; Hagerman et al., 2022; Rouse & Gillespie Rouse, 2022), s'alignant avec la théorie de Seymour Papert (1980). Papert a non seulement souligné l'importance de la manipulation physique des matériaux comme essentielle pour la construction de connaissances plus abstraites, mais il a également mis en avant l'idée que l'acte de bricoler, c'est-à-dire de créer des objets tangibles, permet de rendre le processus d'apprentissage plus concret et engageant pour l'élève. L'intérêt particulier selon le chercheur réside dans « the invention of "objects-to-think-with", objects in which there is an intersection of cultural presence, embedded knowledge, and the possibility for personal identification » (Papert, 1980, p. 11). Ainsi, les personnes construisent leurs connaissances en créant des objets tangibles qui peuvent être exposés, examinés et critiqués, que ce soit à travers la création de produits personnalisés qui ont du sens pour la personne (Searle et al., 2016).

L'élément crucial réside dans l'acquisition du savoir en bricolant un objet partageable (Martinez & Stager, 2013), qui favorise ainsi un échange de savoirs et un apprentissage collaboratif.

Mouvement bricoleur

Bien que le terme « maker » soit largement utilisé dans la littérature scientifique anglophone, le manque de publications empiriques en français pose un défi pour sa traduction (Bosqué et al., 2014). Quelques ouvrages francophones font référence au mouvement Maker (Bosqué, 2015; Capdevila, 2016) ou au mouvement des Makers (Hussenot, 2017), cependant, nous adoptons le terme « mouvement bricoleur » (Cotnam-Kappel et al., 2020). En concordance avec les vues des chercheurs qui préconisent de ne pas restreindre excessivement le concept afin de tenir compte de la diversité des activités bricoleur (Vossoughi & Bevan, 2014), nous choisissons un terme français, « bricoler », préservant ainsi l'esprit du mouvement qui vise à démocratiser l'accès au bricolage, compte tenu du fait que diverses activités peuvent être qualifiées de bricoleur, qu'elles impliquent ou non des outils technologiques (Cotnam-Kappel et al., 2020). Ce mouvement se décline en trois dimensions : le « bricolage » en tant qu'ensemble d'activités conçues avec une variété de buts d'apprentissage, les « espaces bricoleur » en tant que communautés de pratique dans lesquelles les bricoleur partagent les ressources, processus et produits, et les « bricoleur », une identité participative adoptée par les apprenants au sein du mouvement (Halverson & Sheridan, 2014). Des études récentes au Canada montrent que les espaces bricoleur partagent des objectifs communs, notamment la démocratisation des outils numériques, la promotion de la créativité et le développement du pouvoir d'agir des bricoleur en tant que membres actifs d'une communauté (Hughes, 2019; Parent et al., 2021).

L'intégration récente du mouvement bricoleur dans les écoles découle de la reconnaissance de son fort potentiel éducatif, notamment pour initier les jeunes au bricolage et développer des valeurs et compétences telles que la curiosité, la créativité et l'*agency* (Martinez & Stager, 2013; Rouse & Gillespie Rouse, 2022). Toutefois, cette intégration du mouvement bricoleur en milieu scolaire suscite également de nombreuses tensions. D'un côté, certains chercheurs associent le mouvement principalement aux disciplines STIM (Vossoughi & Bevan, 2014), tandis que d'autres plaident pour une application plus large incluant les arts et les sciences sociales (Godhe et al., 2019). D'autres insistent sur l'importances des compétences liées au bricolage et à des concepts qui ne sont pas nécessairement abordés dans les programmes-cadres, tels que l'identité ou le *mindset* bricoleur (Clapp et al., 2017; Halverson & Sheridan, 2014). Une autre tension émerge concernant le rôle du personnel enseignant : il leur est suggéré de minimiser leur intervention directe et plutôt rediriger leur autorité dans les espaces bricoleur, favorisant ainsi l'apprentissage autonome des élèves, qui apprennent en utilisant les outils à leur disposition et en collaborant avec leurs pairs ou d'autres membres de la communauté (Clapp et al., 2017; Rouse & Gillespie Rouse, 2022).

Dans cet article, l'expression « projet bricoleur » désigne les activités proposées et réalisées dans le cadre du mouvement bricoleur, qu'elles soient physiques, numériques ou hybrides, et généralement intégrées dans des démarches constructionnistes (Caratachea et al., 2023). Il est également pertinent de noter que, malgré l'abondance de la littérature anglophone sur le sujet, le mouvement bricoleur tente encore de se définir en français (Cotnam-Kappel et al., 2020; Parent et al., 2021). C'est pourquoi nous nous efforçons de mettre en valeur les caractéristiques typiques de ce mouvement à travers une analyse rigoureuse de descriptions de projets bricoleur en mettant en avant leurs spécificités et leurs liens avec tout ce qui est affilié au *maker*, sans faire impasse à la langue française.

Méthodologie

L'approche méthodologique de revue de la portée, suivant un protocole précisant des stratégies transparentes à appliquer pour explorer de manière approfondie la littérature scientifique existante dans un domaine spécifique (Albers & Pattuwage, 2017), a été retenue pour cette étude. Son objectif est d'étudier systématiquement les études, de clarifier les connaissances existantes et de détecter les lacunes éventuelles dans le champ (Munn et al., 2018). Cette méthode, jusqu'à présent peu répandue dans la littérature francophone, est particulièrement pertinente pour étudier des domaines complexes qui n'ont pas encore été évalués dans leur ensemble (Mays et al., 2001 cités par Arksey & O'Malley, 2005), comme c'est le cas pour le domaine naissant de la recherche sur le mouvement bricoleur en éducation, ce qui la distingue de la revue systématique qui vise l'évaluation de la qualité des études et des conclusions utiles pour orienter les politiques publiques (Tricco et al., 2018). Notre étude suit les normes *Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews* (PRISMA-ScR), un protocole visant à améliorer la transparence et à standardiser la publication des revues de la portée à partir de lignes directrices spécifiques pour la présentation de leurs résultats (Page et al., 2021; Tricco et al., 2018).

Revue de la portée : objectifs et stratégie de recherche

Cette revue de la portée a pour objectif de répertorier les études décrivant des projets bricoleur en contextes éducatifs et leurs effets auprès d'élèves de la 4e à la 8e année. Le spectre de notre recherche s'étend à l'international et touche aux contextes éducatifs formels et informels, tels que les écoles, les musées et les camps d'été, mais se limite aux études publiées ces dix dernières années, soit entre 2012 et 2022 afin de repérer les recommandations les plus pertinentes aux contextes technologiques et pédagogiques actuels.

Quant à la stratégie de recherche, un bibliothécaire de recherche ayant une expertise en synthèse de connaissances a créé une stratégie visant à trouver des références indexées dans les bases de données Academic Search Complete (EBSCOhost), ACM Digital Library, Cairn (cairn.info), Canadian Business et Current Affairs (ProQuest), Education Source (EBSCOhost), ERIC (Ovid), Érudit (erudit.org), et Web of Science (Clarivate). Cette stratégie s'est inspirée de celles développées dans d'autres revues exhaustives de la littérature portant sur les espaces bricoleur (Papavlasopoulou et al., 2017; Rouse & Gillespie Rouse, 2022; Schad & Jones, 2020) et fut le sujet de multiples évaluations par les pairs en suivant la norme *Peer-Review of Electronic Search Strategy* (McGowan et al., 2016). Après avoir finalisé la stratégie pour ERIC (Ovid), celle-ci a été adaptée pour d'autres bases de données en tenant compte des différences liées à l'indexation par sujets et à la syntaxe de recherche[1]. La recherche dans les huit bases de données a été effectuée le 16 juin 2022.

Processus d'inclusion et constitution d'un corpus

Les 1 900 références trouvées ont ensuite été importées dans Covidence, un outil en ligne qui permet de travailler en collaboration dans un traitement en double aveugle durant les différentes étapes de la revue. Pour assurer une plus grande rigueur et minimiser les conflits dans Covidence, un projet pilote a été mené pour évaluer 20 références choisies aléatoirement. Une fois les références importées, 638 doublons ont été supprimés. Notre équipe de recherche composée de trois personnes a, par la suite, procédé à examiner les titres et résumés des 1 262 références restantes pour en vérifier l'admissibilité selon les critères d'inclusion. Pour être admissibles, les articles repérés devaient répondre aux critères d'inclusion suivants :

- L'article concerne les élèves de la 4e à la 8e année, soit de 9 à 14 ans (critère : participant)
- Le texte est un article scientifique revu par les pairs (critère : type de publication)
- L'article mentionne explicitement des activités bricoleur physique ou numérique, leur déroulement, leurs retombées et/ou pratiques gagnantes (critère : sujet)
- L'article inclut des données empiriques (critère : méthode)
- L'article est rédigé en français ou anglais (critère : langue)

Une fois cette étape terminée, un autre pilote a été fait avec 15 articles en texte intégral. Ensuite, l'équipe a évalué le texte intégral de 263 articles admis à la suite de la première étape d'évaluation. Parmi ceux-ci, 195 ont été exclus en raison du mauvais type de participants (n = 69), du mauvais sujet (n = 56), du mauvais type de publication (n = 47), de mauvaises méthodes (n = 21), par exemple une recension des écrits ou article théorique, et de langue autre que le français ou l'anglais (n = 2). Malgré nos efforts en tant qu'équipe de recherche bilingue pour explorer les bases de données en français et en anglais, nous tenons à noter que huit références parmi les 263 étaient en français, mais elles ont été exclues selon nos critères d'inclusion, et aucun article en français n'a été retenu dans le corpus final. Finalement, 68 études répondaient à nos critères d'inclusion et ont été codées puis analysées par notre équipe.

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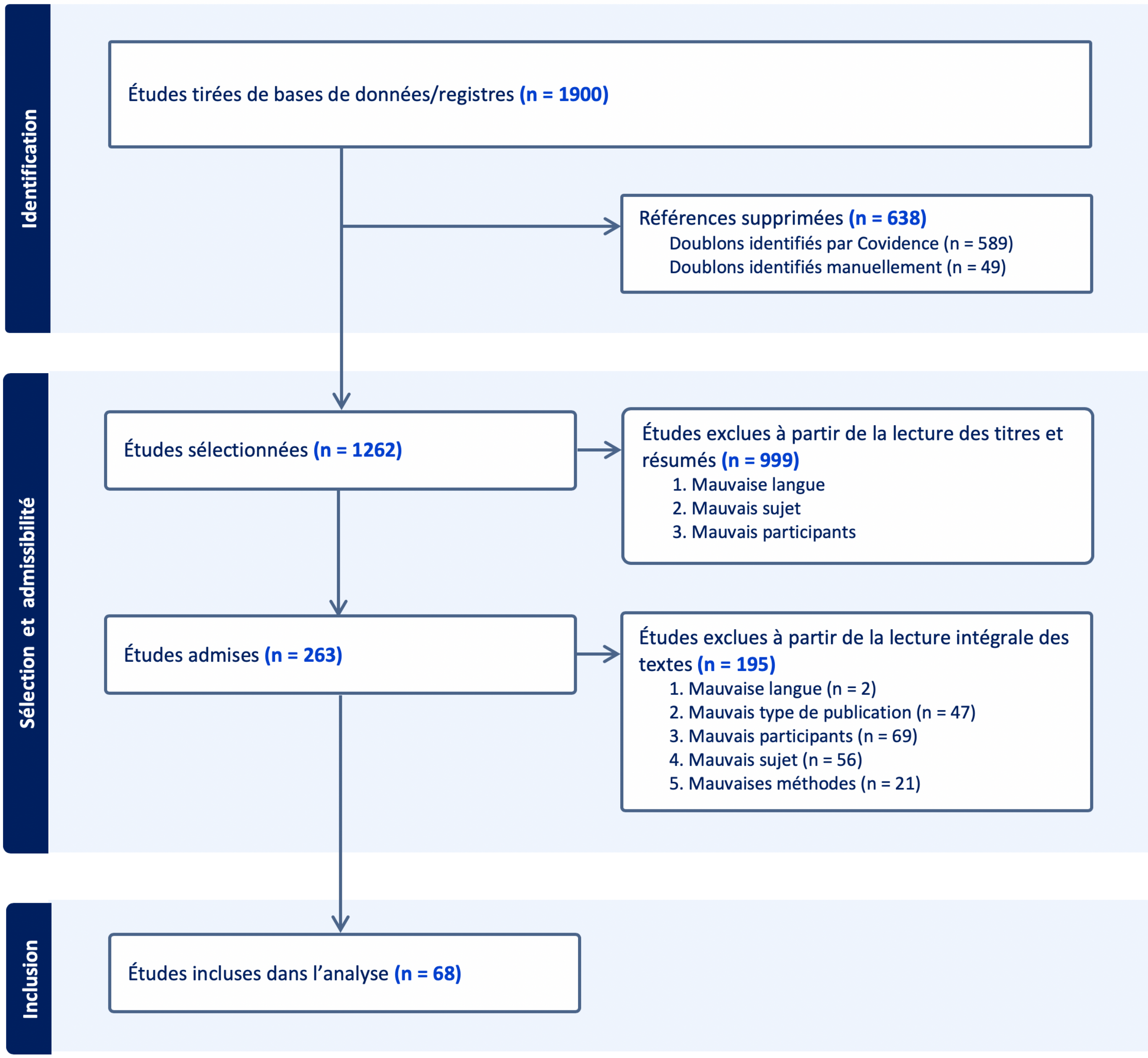
[1] Étant donné la complexité et le nombre élevé de mots-clés utilisés dans un total de huit bases de données, nous ne pouvons pas tous les inclure dans cet article. Cependant, un document séparé est disponible sur demande auprès de l'autrice correspondante pour obtenir la liste détaillée, ainsi que les stratégies de recherche complètes pour chaque base de données.

Figure 1

Diagramme de flux



Extraction des données

Nous avons privilégié le logiciel d'analyse de données Dedoose pour le codage des données. Le codage des 68 études retenues a été réparti entre les trois membres de l'équipe et réalisé à partir d'une liste non exhaustive de codes inspirés de nos questions de recherche et correspondant au modèle PCC (Peters et al., 2020) – PCC pour population, contexte, concepts. Cette liste a été complétée au fur et à mesure de nouveaux codes émergeaient, et ce, dans une approche inductive générale (Blais & Martineau, 2006). Le Tableau 1 résume les codes pour lesquels les données ont été extraites. Pour une raison de lisibilité, seulement les exemples de sous-codes les plus pertinents y sont mentionnés.

Tableau 1

Liste non exhaustive des codes et sous-codes utilisés sur Dedoose selon le modèle PCC

	Population	Contexte	Concepts
Code	Participants	Contexte de bricolage	Effets
Sous-code	*âge et/ou année*	*où (en classe, dans un makerspace, en ligne), quand (durant les cours, en dehors des cours), avec (enseignant·es, bibliothécaire)*	*sur les jeunes, sur les enseignant·es* *playful teaching or learning*
		Activité maker identifiée	Déroulement
		Physique, numérique, hybride	*Pédagogie, évaluation*
		Pays	Défi
			Recommandation

Analyse des données

En nous inspirant de l'approche inductive générale (Blais & Martineau, 2006; Thomas, 2006), nous avons procédé en premier lieu à un codage inductif au moyen du logiciel Dedoose pour condenser les données brutes. Par la suite, nous avons établi des liens entre nos objectifs de recherches et nos catégories émergentes, par exemple au moyen de catégories intitulées « déroulement » et « retombées ». Finalement, nous avons développé des contributions nouvelles à partir des catégories et de leurs sous-codes, à titre d'exemple sous « Retombées – élèves », on retrouve les codes 1) dimensions affectives, 2) dimensions sociales, 3) apprentissages disciplinaires, et 4) compétences métacognitives et stratégiques.

Limites

Nous reconnaissons que notre revue comporte certaines limites qui pourraient influencer les résultats. Notre objectif était d'examiner les projets bricoleur chez les élèves de la 4^{e} à la 8^{e} année (9 à 14 ans). Nous avons exclu les livres, chapitres, thèses et rapports, et il est possible que certaines études non indexées aient échappé à nos recherches. Bien que notre démarche ait été rigoureuse, elle demeure sujette à des biais. De plus, en nous concentrant uniquement sur les études empiriques, nous avons laissé de côté les études théoriques. Bien que nous ayons largement couvert le domaine avec une recension de plus de soixante articles, il reste que notre analyse est principalement orientée vers les aspects pratiques en salle de classe.

Résultats

Les résultats révèlent que les cinq principaux pays ayant contribué à la recherche sur les projets bricoleur dans des classes de l'élémentaire sont les États-Unis (n = 19), la Finlande (n = 9), le Canada (n = 7), l'Espagne (n = 4), et la Chine (n = 3). Dans cet article, nous explorons deux thèmes principaux :

premièrement, la description des projets bricoleur incluant contenu et outils, puis leur déroulement et mise en pratique auprès d'élèves de la 4e à la 8e année. Deuxièmement, nous offrons un aperçu des retombées rapportées dans les articles du corpus touchant à la fois les élèves et le personnel enseignant. À noter que *n* représente le nombre d'articles traitant de chaque thème ou catégorie.

Portrait des activités de bricolage

Notre corpus de 68 articles révèle que 33 décrivent en détail le déroulement des projets bricoleur. Bien que la majorité de ces projets soient intégrés dans un cadre disciplinaire et au service des programmes-cadres (n = 25), 16 des activités recensées dépassent les disciplines formelles parce qu'elles touchent notamment au développement individuel et communautaire. Par ailleurs, nous relevons un nombre équivalent d'outils, de matériaux et de ressources de type physique (n = 18) que numérique (n = 19). Étonnamment, plus de la moitié des activités (n = 11) sont de nature hybride, combinant outils physiques « et » numériques.

Le bricolage indiscipliné : tendance à l'inter- et à la transdisciplinarité

Les projets bricoleur recensés servent le développement de compétences et de savoirs disciplinaires (n = 25) en lien avec les littératies traditionnelles et numériques (n = 8) et les arts (n = 4), mais surtout les sciences (n = 7), les technologies (n = 10), l'ingénierie (n = 4), et les mathématiques (n = 5) que nous regrouperons sous l'acronyme STIM (plus connues en anglais sous *STEM*). Il est toutefois nécessaire de souligner le caractère interdisciplinaire des projets bricoleur puisque nous notons de nombreux chevauchements entre les disciplines, que ce soit à travers les STIM ou avec les littératies.

L'article de Montgomery et Madden (2019) illustre l'interdisciplinarité entre littératies et ingénierie. Elles décrivent un projet où les élèves sont invités à explorer et à expérimenter leur compréhension littéraire en s'engageant dans un processus de construction des connaissances où ils identifient un problème rencontré par un personnage de fiction. Ils sont ensuite chargés de concevoir un artefact adapté pour résoudre ce problème avec les matériaux disponibles dans la classe, par exemple du bois, de la corde et des poulies. Toujours dans cette idée d'interdisciplinarité, Hughes et al. (2019) indiquent que les premières séances des projets bricoleur sont d'abord consacrées à l'enseignement des littératies numériques puisque « bricoler (*making*) implique d'abord de repérer les ressources matérielles et intellectuelles et de comprendre comment ces ressources s'articulent les unes par rapport aux autres » (traduction libre, p. 315). Dans cet exemple, par ressources intellectuelles, on entend le développement de littératies numériques liées à la création d'affiches numériques et à la vidéographie. Ces littératies sont généralement abordées à travers la composition multimodale (Dalton, 2020; Hagerman et al., 2022) pour exprimer leur compréhension d'un sujet. Les possibilités d'écriture créative se déclinent alors sous différents genres et médiums, sous forme papier et/ou numérique : la bande dessinée (Assaf et al., 2021), le récit de science-fiction (Dalton et al., 2020), l'histoire numérique (Bull et al., 2017), la vidéo (Assaf et al., 2021), ou la présentation de diaporama (Hagerman et al., 2022).

Du côté des STIM, les projets recensés couvrent tous les âges et répondent aux disciplines et aux besoins curriculaires. En sciences, on retrouve des projets touchant aux énergies renouvelables (Chen & Lin, 2019), à la consommation d'énergie (Mylonas et al., 2019), à l'optique (Bevan et al., 2020) et à la santé (Geser et al., 2019). Les activités décrites par Mylonas et al. (2019) ainsi que par Geser et al. (2019) se démarquent des autres par leur lien avec la vie quotidienne des élèves, contextualisant et donnant un sens à leurs apprentissages. Par exemple, l'étude de l'empreinte énergétique de leur école (Mylonas et al., 2019) et le développement d'une barre granola santé adapté aux besoins nutritifs d'enfants (Geser et al., 2019) impliquent les élèves dans la conceptualisation du produit jusqu'aux aspects marketing, en passant par la production, renforçant ainsi leur engagement et leur compréhension.

En technologie, les électroniques sont largement intégrées aux contenus d'apprentissage de projets bricoleur, couvrant la familiarisation avec les circuits électriques (Bevan et al., 2020; Blackey et al., 2018), l'expérimentation (Hansen et al., 2019) et la création d'artefacts intégrant des composants électroniques tels que les *e-textiles*. Des exemples incluent des marionnettes électroniques (Buchholz et al., 2014), des chandails chauffants ou encore des vestes anti-viol (Barton et al., 2017). En ingénierie, on note des activités liées à la robotique : fabrication de robots (Hansen et al., 2019), création d'un *waste robot* (Geser et al., 2019), d'une manette de jeu ou d'un lecteur de musique (Harlow & Hansen, 2018). En mathématiques, Ke et al. (2019) proposent d'aborder la résolution de problèmes en *e-rebuild* à travers les jeux vidéo. Weng et al. (2022) partagent l'exemple d'activités de résolution de problème basée sur un jeu vidéo créé par les jeunes avec Scratch.

Parmi les activités mêlant disciplines scientifiques, technologiques, ingénieriques, artistiques, et mathématiques (STIAM), nous pensons notamment à la création de *e-sculptures* (Friend & Mills, 2021) ou imaginer et produire un jouet 3D (Fu et al., 2022), un projet ayant amené les jeunes à se familiariser autant avec des modes de production créatifs (conception d'un design), que technologiques (modélisation sur ordinateur), et artistiques (peinture, présentation artisanale, et créative).

Au-delà de ce cadre académique et interdisciplinaire, nous remarquons une tendance à la transdisciplinarité. Plus d'un tiers des articles étudiés présentent les projets bricoleur comme étant d'abord orientés vers l'individu (n = 5) ou la communauté (n = 7), plutôt que vers des objectifs curriculaires formels, et proposés sous la forme de défis (n = 7). Selon Leinonen et al. (2020), ces projets favoriseraient une culture d'apprentissage favorable à l'estime de soi et au pouvoir d'agir de l'élève. Elles peuvent aussi valoriser l'identité de l'élève, par exemple, *via* la production d'un journal réflexif (Hughes, 2017) ou de design (Martin et al., 2020).

Les défis proposés varient, allant de ceux choisis par l'élève (Barton et al., 2017; Herro et al., 2021a; Kumpulainen et al., 2020) à ceux imposés par l'adulte (Wright et al., 2018), et peuvent être réalisés individuellement ou en groupe (Hansen et al., 2019; Kajamaa & Kumpulainen, 2019). L'enseignant·e peut aussi participer aux activités et collaborer avec les élèves (Mylonas et al., 2019). Le défi peut également être destiné à servir un groupe à l'extérieur de l'école en répondant à un besoin des membres de la communauté (Hansen et al., 2019). Quoi qu'il en soit, l'objectif derrière ces défis de bricolage est de voir des élèves motivés et actifs dans leur apprentissage en les laissant expérimenter, découvrir et manipuler le matériel disponible.

Les projets bricoleur peuvent aussi adopter une approche sociale et communautaire, permettant aux élèves d'avoir une influence sur leur communauté (Assaf et al., 2021; Barton et al., 2017). Ces activités sont basées sur des besoins réels de la communauté, avec des élèves enquêtant et proposant des solutions concrètes. Par exemple, Hansen et al. (2019) décrivent une classe de jeunes âgés de 13 à

14 ans qui ont réalisé une prothèse qui serait utilisée lors d'un tournage par un cascadeur professionnel amputé d'une partie de sa jambe, tandis que Thanapornsangsuth et Holbert (2020) mentionnent des élèves développant un parapluie tout usage qui protège de la pluie, du soleil et de la chaleur; et un robot accueillant censé attirer davantage de clientèle pour des vendeurs de rue de leur communauté. De plus, les activités de bricolage sont également une opportunité de sensibiliser les jeunes sur les questions sociales et de justice (Hughes, 2017; Hughes et al., 2019; Trust, 2018).

Le bricolage hybride : outils et matériaux

Notre analyse révèle que les articles de notre corpus mentionnent presque également l'utilisation d'outils ou de matériaux physiques (n = 18) et numériques (n = 19), avec une prédominance d'activités hybrides (n = 11) combinant les deux. Les matériaux physiques comprennent les matériaux recyclés (n = 4), le matériel électronique (n = 13), les livres (n = 2), et autres (n = 2), par exemple son corps lorsqu'on incorpore la danse dans son enseignement (Herro et al., 2021b). Le Tableau 2 présente quelques exemples d'activités utilisant ces outils, mais nous recommandons de consulter les textes cités pour des descriptions plus exhaustives.

Tableau 2

Outils, matériaux et ressources physiques : quelques exemples

Catégorie	Nom	Exemple d'activité	Âge	Référence
Matériaux recyclés	Bois, tissu, carton, boîte en plastique	*Les élèves proposent une solution à un problème d'un personnage du livre en utilisant des matériaux disponibles.*	*10-11*	Montgomery et Madden (2019)
Électronique	LilyPad Arduino	*Les élèves fabriquent leur propre chapeau lumineux en utilisant le e-textile.*	*11-13*	Hébert et Jenson (2020)
Littératie	Livre illustré BD	*Les jeunes conçoivent un superhéros, créent ses outils et réfléchissent à leur propre pouvoir dans leur communauté.*	*7-13*	Assaf et al. (2021)

Parmi les outils, les ressources et les matériaux numériques, nous avons identifié quatre catégories : logiciels (n = 10), technologies (n = 16), programmes (n = 5), et littératies numériques (n = 4). Le Tableau 3 résume quelques exemples d'activités.

Nous déplorons l'absence criante de ressources disponibles en français. À notre connaissance, sont seulement disponibles en français les ressources suivantes : Scratch, un outil conçu pour le codage de jeux, d'histoires et animations numériques; Tinkercad, une application web gratuite destinée à la conception 3D, l'électronique et au codage; et Ultimaker Cura, un logiciel d'impression 3D.

Tableau 3

Outils et matériaux numériques : quelques exemples

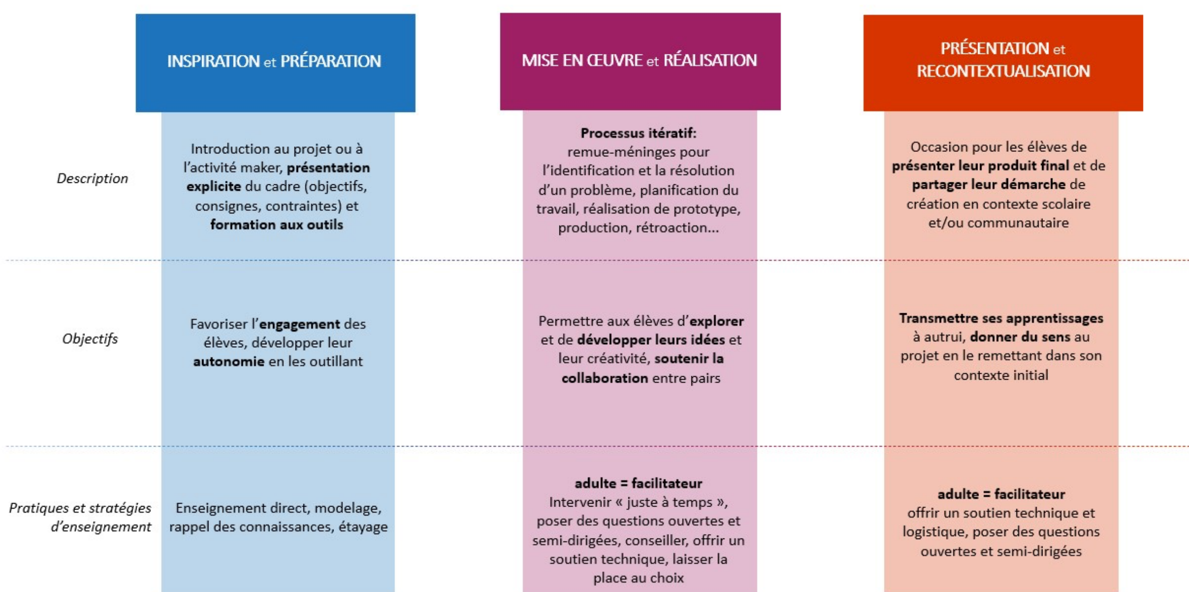
Catégorie	Nom	Exemple d'activité	Âge	Référence
Logiciel	Design graphique	*Les élèves plus agé·es collaborent avec les jeunes de maternelle pour fabriquer les « jouets de leurs rêves ».*	*9-10*	Holbert (2016)
Technologie	Imprimante 3D	*Au choix, les élèves produisent une pièce de jeu ou un objet fonctionnel.*	*10-14*	Leinonen et al. (2020)

Déroulement d'un projet bricoleur

Nos analyses mettent en lumière le contexte des projets bricoleur, révélant que la majorité ont lieu durant les heures de classe (n = 28), tandis qu'une minorité se déroule après l'école (n = 6). Elles prennent place dans la salle de classe (n = 8), dans l'espace bricoleur de l'école (n = 9), ou encore dans un endroit extérieur à l'école (n = 11) telle une bibliothèque ou une université. Nos analyses inductives des descriptions de projets bricoleur avec des jeunes de la 4^e^ à la 8^e^ année ont révélé une structure en trois phases distinctes : a) inspiration et préparation, b) mise en œuvre et réalisation, puis c) présentation et recontextualisation (Figure 2).

Figure 2

Déroulement en trois phases des activités et des projets bricoleur



a) Phase d'inspiration et de préparation

La phase d'inspiration et de préparation fait office d'introduction au projet bricoleur. Il s'agit de proposer une activité d'ouverture attrayante et porteuse de sens pour les élèves afin de piquer leur curiosité, leur intérêt et susciter leur engagement envers le projet. Selon le projet, cette activité peut comprendre la lecture de bandes dessinées (Assaf et al., 2021), la projection de vidéos (Becker & Jacobsen, 2019), une marche d'observation (Assaf et al., 2021) ou une invitation pour les élèves à amener en classe un article de leur intérêt (Becker & Jacobsen, 2019). L'idée est de provoquer une discussion, une réflexion, et à ouvrir un dialogue visant à inspirer et à préparer les élèves au processus de bricolage. Selon les études recensées, cette première phase peut aussi représenter l'occasion pour le personnel enseignant de faire un rappel des connaissances (Ng & Chan, 2019), de présenter explicitement les objectifs, consignes et contraintes liées au projet (Chen & Lin, 2019), de former les élèves à l'utilisation de nouveaux outils par modelage (Weng et al., 2022) et de leur proposer des ressources (ex., guide visuel, tutoriel en ligne) pour encourager un travail autonome (Hughes et al., 2019).

b) Phase de mise en œuvre et de réalisation

Notre analyse des projets bricoleur recensés révèle que la deuxième phase plonge les élèves dans la mise en œuvre et la réalisation de leur bricolage. Cette phase inclut diverses étapes clés, telles que l'identification d'un problème et la recherche d'une résolution (ex., remue-méninges, créer un sondage pour interroger un groupe cible), la planification du travail (ex., répartition des rôles ou des tâches entre les élèves), la réalisation d'un prototype, la production de l'artefact et la rétroaction (par les pairs ou le groupe cible). Ce processus a un aspect itératif, puisque l'on peut revenir à une étape ou l'autre lorsque nécessaire. Par exemple, Geser et al. (2019) décrivent des élèves analysant la production de jeans, puis qui créent un robot gestionnaire de déchets en deux phases, d'abord avec des matériaux recyclés, puis en utilisant la fabrication numérique.

Dès lors, l'adulte en classe agit en tant que facilitateur, intervenant « juste à temps » auprès des élèves de manière consistante et encourageante (Hughes et al., 2019, p. 315) pour offrir une assistance technique ou un conseil (Ng & Chan, 2019), et attirant leur attention sur des problèmes éventuels qui seraient à anticiper ou sur les contraintes du projet (Herro et al., 2021b; Ng & Chan, 2019). Par ailleurs, les groupes peuvent disposer de différents outils tout au long du projet afin de les aider à structurer leur travail, à commencer par un journal de bord (Hsu et al., 2019). Des fiches de planification de type *genius hour* (Bishop & Lepou, 2019) permettent également aux jeunes de guider leur réflexion et de construire pas à pas leur projet. De même, un tableau répertoriant le type de ressource (ex., vidéo, biographie), l'URL et « ce que j'ai appris de cette ressource » peut faciliter l'étape de recherche (Trust, 2018, exemple à la p. 105).

c) Phase de présentation et de recontextualisation

Pour finir, la phase de présentation et de recontextualisation qui émerge de nos analyses des projets de notre corpus permet aux élèves d'exposer leur produit final et de partager leur processus créatif, soit en milieu scolaire ou communautaire. La présentation peut s'adresser à différents publics, soit aux autres groupes de la classe, aux parents, au personnel scolaire ou aux membres de la communauté (Thanapornsangsuth & Holbert, 2020; Trust, 2018). La présentation peut aussi prendre une variété de formes : une forme classique avec une présentation orale (appuyée par un support visuel ou multimodal); une forme participative en montant une exposition (Kendrick et al., 2020), en prenant part à une compétition externe ou une foire scientifique (Chen & Lin, 2019); ou encore une forme numérique en créant une galerie en ligne (Google sites ou Photos, Adobe Spark, Instagram, Pinterest, Flickr, ou Padlet), ou en partageant la nouvelle par courriel ou à travers les réseaux sociaux (Trust, 2018). Il y a donc une recontextualisation du projet. Les pratiques enseignantes relevées ici sont similaires à celles décrites dans la phase de mise en œuvre et de réalisation.

En guise de synthèse, il faudrait souligner certaines conditions didactiques caractéristiques du déroulement des projets bricoleur recensés. Il s'agit d'insister sur des pratiques visant un étayage et donc favorisant le développement de l'autonomie; il s'agit aussi d'offrir des espaces de collaboration et d'accorder une place au choix des jeunes. À noter que ces pratiques et stratégies semblent s'inscrire dans un modèle d'enseignement éminemment socioconstructiviste, mais intégrant l'enseignement direct de façon ponctuelle et mesurée. Voilà ce qui est en des tendances révélées dans notre corpus. Toutefois, l'une des pistes qui émerge et se démarque serait la place nouvelle de la communauté au sein des activités/projets du mouvement bricoleur.

Pour ce qui est des tensions identifiées, nous souhaitons souligner le manque d'informations sur les moyens et outils d'évaluation qui pourraient être utilisés pour suivre les apprentissages faits lors d'un projet bricoleur. Seulement quatre articles de notre corpus évoquent la question de l'évaluation. Certains proposent des moyens d'évaluation classiques (dirigés par l'adulte) telles que l'observation (Harlow & Hansen, 2018) ou la grille d'évaluation (Trust, 2018); d'autres soulignent le rôle actif des jeunes dans leur propre évaluation, spécifiquement à travers le journal réflexif (Becker & Jacobsen, 2019) tandis que d'autres encore mentionnent une approche plus ludique de l'évaluation notamment avec l'attribution d'un permis de conduire 3D pour sanctionner la maîtrise d'outils de conception et d'impression 3D (Leinonen et al., 2020).

Aperçu des retombées des projets bricoleur pour les élèves et le personnel enseignant

Cinquante-neuf des études de notre corpus (n = 68) présentent les retombées des activités sur les élèves et seuls 15 explorent les retombées sur le personnel enseignant, tant sur le plan affectif et social, que dans les apprentissages disciplinaires et les compétences stratégiques et métacognitives. Concernant le personnel enseignant, des retombées affectives, sociales et pédagogiques ont également été observées.

Quarante-neuf des 68 articles présentent des résultats affectifs rapportés pour les élèves qui comprennent le développement d'un sentiment de plaisir (n = 17), de confiance (n = 12), de l'agency (n = 12), de confiance (n = 12), d'*empowerment* (n = 10), d'enthousiasme (n = 10), de créativité (n = 9), et de curiosité (n = 4). Trente et un articles ont indiqué une augmentation de la motivation et de la participation liés aux projets bricoleur. En outre, quelques études soulignent les retombées affectives (n = 4), notamment en quoi les projets renforcent la confiance du personnel, favorisent le développement de leur pouvoir d'agir et de leur identité de bricoleur (ex., Becker & Jacobsen, 2021; Chen & Lin, 2019). Par ailleurs, les résultats de nombreuses études soulignent les retombées et aspects sociaux du mouvement bricoleur pour les élèves (n = 32), notamment des effets sur la communication, la participation et la collaboration (n = 24) (ex., Iwata et al., 2020; Riikonen et al., 2020), et les occasions d'incorporer et de développer les voix et identités des apprenants en créant (n = 7) (ex., Leinonen et al., 2020; Ng & Chan, 2019). Du côté du personnel enseignant, l'amélioration sociale (n = 5) se manifeste par une collaboration accrue entre collègues en matière d'idéation, d'organisation et d'évaluation (Riikonen et al., 2020) ainsi que plus de leçons inspirées par les idées et cultures des élèves, permettant d'établir une meilleure connexion avec eux (ex., Tofel-Grehl et al., 2020).

Tableau 4

Retombées positives rapportées des projets bricoleur

Retombées positives rapportées	Acteurs concernés	
Dimensions affectives	Élèves (n = 49)	Personnel enseignant (n = 4)
Dimensions sociales	Élèves (n = 32)	Personnel enseignant (n = 5)
Apprentissages disciplinaires	Élèves (n = 25)	-
Compétences métacognitives et stratégiques	Élèves (n = 25)	-
Dimensions pédagogiques	-	Personnel enseignant (n = 14)

Les projets bricoleur favorisent également les apprentissages disciplinaires (n = 25), avec l'acquisition de compétences rapportées en STIAM (n = 9), en sciences (n = 7), en mathématiques (n = 6), et en génie (n = 4) ainsi que des compétences en littératies numériques (n = 8), traditionnelles (n = 6), multimodales (n = 3), et bricoleur (n = 2), grâce à leur engagement dans ces projets. Elles renforcent les compétences métacognitives et stratégiques des élèves (n = 25), stimulant par exemple la résolution de problèmes (n = 16), la pensée critique (n = 8), la créativité (n = 10), et la pensée design (n = 3) (ex., Harlow & Hanson, 2018; Montgomery & Madden, 2019). En outre, 14 articles du corpus décrivent aussi comment le personnel enseignant, qui adopte des approches collaboratives centrées sur l'élève et basées sur l'apprentissage par la fabrication, constate une influence positive sur leurs pratiques (ex., Fu et al., 2022; Iivari et al., 2018) et dispositions pédagogiques (ex., Barton et al., 2017; Tofel-Grehl et al., 2020).

Discussion

Dans cette revue de la portée, notre objectif était d'explorer les descriptions des projets bricoleur et les retombées rapportées de celles-ci en contextes éducatifs de la 4e à la 8e année. Au cours de notre étude, nous avons repéré 68 articles pertinents et leur analyse offre des pistes clés pour une meilleure formation enseignante s'appuyant sur un grand éventail d'études empiriques sur le déroulement et les retombées de projets bricoleur.

Descriptions des projets bricoleur

Parmi les descriptions des projets bricoleur dans notre corpus, nous notons une intégration importante de projets dans des cadres disciplinaires liées aux programmes-cadres (n = 25). L'étude révèle une sous-représentation des littératies (n = 8), à la fois traditionnelles et numériques, et des arts (n = 4) par rapport aux disciplines STIM (n = 26), raison pour laquelle les futures recherches devront se focaliser davantage sur une distribution plus équilibrée entre les disciplines, notamment les aspects littératies et artistiques des projets bricoleur, et sur les projets inter- et transdiciplinaires (ex., entre littératies et ingénierie dans Montgomery & Madden, 2019). Ces résultats soulignent ainsi la nécessité d'une formation enseignante approfondie sur l'inter- et la transdisciplinarité, pour préparer adéquatement le personnel à créer et à intégrer de tels projets bricoleur dans leur enseignement. Par ailleurs, seules 3 études sur 68 abordent les projets bricoleur orientés vers l'équité (Barton et al., 2017), ce qui suggère un besoin criant dans le domaine pour des recherches sur les projets bricoleur centrés sur les cultures, les voix et le pouvoir des jeunes (Vossoughi et al., 2016).

Notre corpus révèle un équilibre entre outils physiques et numériques ainsi que les nombreux projets qui se distinguent par leur dimension hybride, alliant outils et matériaux physiques et numériques (n = 11). Cela suggère que les projets bricoleur ne doivent pas se limiter à cette dichotomie entre matériel tangible et technologie numérique, mais qu'ils tirent parti de la complémentarité pour enrichir l'expérience d'apprentissage (Assaf et al., 2021; Ramey & Stevens, 2019). Des recherches futures pourraient explorer comment cet équilibre entre outils influence l'expérience des élèves ainsi que les types de formations les plus efficaces pour aider les personnels enseignants à intégrer cette dimension hybride dans leurs pratiques pédagogiques.

Déroulement des projets bricoleur en trois phases

L'analyse du déroulement des projets bricoleur révèle une structure en trois phases distinctes, soit 1) inspiration et préparation, 2) mise en œuvre et réalisation, et 3) présentation et recontextualisation. Ces phases soulignent le rôle central du personnel enseignant comme facilitateurs et le potentiel des projets bricoleur pour développer l'autonomie et la créativité des élèves (Chen & Lin, 2019; Geser et al., 2019). La Figure 2 qui précise ces phases constitue une contribution théorique notable de l'article en fournissant un modèle pédagogique structuré et adaptable pour orienter le personnel enseignant dans la création et la mise en œuvre de projets bricoleur. Ces phases mettent en exergue l'importance d'une pédagogie dynamique, centrée sur l'élève, qui encourage l'exploration et l'expression personnelle (Becker & Jacobsen, 2021; Clapp et al., 2017). Pourtant, avec seulement quatre articles qui font mention de l'évaluation des projets bricoleur dans le corpus, nos analyses dévoilent que l'évaluation représente toujours un défi particulier pour l'intégration de projets bricoleur (Murai & San Juan, 2023), et de futures recherches devraient s'attacher à définir des stratégies d'évaluation adaptées aux projets bricoleur, comme en témoignent les approches innovantes mentionnées par Leinonen et al. (2020).

Les retombées des projets bricoleur

Les retombées des projets bricoleur, telles qu'explorées dans notre corpus, se révèlent notables à la fois pour les élèves et le personnel, bien que les études se concentrent davantage sur les élèves (n = 59) que le personnel (n = 15). Les retombées pour les élèves sont variées et se manifestent tant sur le plan social, disciplinaire que métacognitif. La grande majorité des articles (n = 49) rapportent des retombées affectives pour les élèves, incluant notamment l'augmentation du plaisir, de la confiance, du pouvoir d'agir et favorisant ainsi une participation active et créative au sein de l'espace éducatif. Les retombées affectives et sociales sur le personnel enseignant, quoique moins documentées, révèlent une potentialité similaire pour le développement professionnel, notamment dans la capacité d'établir des liens plus profonds avec les élèves et de s'engager dans des pratiques pédagogiques collaboratives. Les futures recherches devraient s'orienter vers une exploration plus approfondie de l'incidence de ces activités sur le personnel enseignant, ce qui implique une réflexion sur la manière dont les personnes enseignantes peuvent être mieux préparées à intégrer, encourager et évaluer de telles activités dans leurs pratiques pédagogiques quotidiennes (Cotnam-Kappel et al., 2020).

Bien qu'il soit évident que les projets bricoleur offrent un terrain fertile pour le développement d'une pédagogie dynamique et engageante, la formation enseignante doit évoluer en fonction des résultats de ces recherches empiriques pour que le personnel et les élèves exploitent pleinement ce potentiel.

Conclusion

Dans cet article, nous avons analysé le déroulement, les outils et les retombées des projets bricoleur en contextes éducatifs auprès d'élèves de la 4e à la 8e année à travers le monde au moyen d'une revue de la portée dans le but de mieux orienter l'intérêt croissant d'incorporer une formation bricoleur dans les programmes de baccalauréat à l'enseignement (Cotnam-Kappel et al., 2020; Jin & Harron, 2022). Sur le plan de la formation enseignante, ces résultats offrent des pistes essentielles. D'une part, nos programmes de formation doivent non seulement initier les futures enseignantes et futurs enseignants aux outils physiques et numériques nécessaires, mais aussi leur fournir des cadres pédagogiques constructionnistes solides ainsi que des stratégies d'évaluation innovantes pour imaginer et réaliser leurs projets bricoleur. D'autre part, il est crucial que toute formation professionnelle soit pensée dans une optique d'équité, toujours sous-représentée dans les recherches, veillant à ce que les projets ne reproduisent pas des inégalités, mais valorisent les voix des jeunes (Hughes et al., 2019; Vossoughi et al., 2016). Les futures recherches devront élargir le spectre d'investigation pour couvrir de manière plus exhaustive les dimensions sociales, culturelles et équitables du mouvement bricoleur en éducation et nous soulignons le besoin important pour plus de recherches en français sur ce sujet. Mieux comprendre le déroulement, les outils et les retombées de projets bricoleur permet de faire évoluer la formation enseignante pour mieux préparer à la fois enfants et adultes à évoluer dans un paysage éducatif en constante évolution, où l'apprentissage, la créativité et le bricolage sont au premier plan.

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Into the Open: Shared Stories of Open Educational Practices in Teacher Education

À découvert : des histoires partagées de pratiques éducatives libres dans la formation des enseignants

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Abstract

Navigating through the Faculty of Education as a teacher educator in Canada is complex and complicated. Research literature calls for an intentional focus on media and digital literacies, and technological competencies, in teacher education. Program directions are confounded by technological trends emerging in kindergarten to grade twelve education and higher education. This post-intentional phenomenological research study examined moments, materials, and insights from the stories shared by participants as they revealed media and digital skills, fluencies, competencies, and literacies in their open educational practice. This research provides insights into how teacher educators seize opportunities to work through complex matters while applying technology resources. It is becoming ever more important to share expertise as practitioners, researchers, and theorists in the field of education by making explicit what is often tacit and unspoken, and when sharing knowledge, reflections, and actions. By actively thinking-out-loud through blogs, social media, and open scholarly publications, educators can openly share details of *what, how, and why* they *do what they do*. Research findings reveal the importance of media and digital literacies in the dimensions of communication, creativity, connections, and criticality within an open educational practice as a teacher educator.

Keywords: Canadian, digital technology, faculties of education, open educational practices, teacher educators

Résumé

Il est complexe et compliqué de se familiariser avec les attentes de la Faculté d'éducation en tant que formateur d'enseignants au Canada. La littérature scientifique relative à la formation des enseignants invite à mettre l'accent sur les compétences médiatiques et numériques, ainsi que sur les compétences technologiques. Les orientations du programme sont dictées par les tendances technologiques qui se dessinent dans l'enseignement de la maternelle au secondaire, ainsi que dans l'enseignement supérieur. Cette étude phénoménologique post-intentionnelle s'est penchée sur des moments, du matériel et des idées que les participants ont partagés dans le cadre de leur pratique éducative libre, ce qui a permis de révéler leurs aptitudes, compétences et niveau de littératie médiatiques et numériques. Cette approche permet de comprendre comment les formateurs d'enseignants se saisissent des ressources technologiques pour aborder des questions complexes. Il devient de plus en plus important de partager l'expertise des praticiens, des chercheurs et des théoriciens dans le domaine de l'éducation, car cela révèle souvent ce qui est tacite et non-dit, et permet de partager des connaissances, des réflexions et des actions. Le fait de réfléchir à chaud grâce aux blogues, aux médias sociaux et aux publications savantes ouvertes est une façon pour les éducateurs de partager ouvertement *ce* qu'ils font, *comment et pourquoi* ils *font ce qu'ils font*. Les résultats de notre étude révèlent l'importance des compétences médiatiques et numériques en matière de communication, de créativité, de connexions et d'esprit critique au sein de la pratique éducative libre de formateurs d'enseignants.

Mots-clés : Canadiens, technologie numérique, facultés d'éducation, pratiques éducatives libres, formateurs d'enseignants

Introduction

Navigating through teacher education programs in Canada is complex and complicated. For those who teach in faculties of education, competing demands include higher education policies as well as education mandates from provincial sectors for kindergarten to grade twelve curriculum. Additionally, faculty of education program directions are confounded by technological trends emerging in both higher education and the K-12 sector. When considering digital literacy, there are frequent calls from business and industry for a nationwide, cohesive strategy (Hadziristic, 2017). Contributing to this are the growing demands at both the national and global levels for digitally proficient students and educators (McAleese & Brisson-Boivin, 2022; McLean & Rowsell, 2020; UNESCO, 2022, 2023). These pressures and tensions in teacher education are exacerbated with issues of fiscal restraint and the aftermath of pandemic-influenced, technology-driven teaching and learning constraints (Danyluk et al., 2022).

Goodwin and Kosnik (2013) suggested a need for research into how teacher educators perform. Research recommended a closer examination into what it means to be a teacher educator (Ellis & McNicholl, 2015). Now it becomes ever more important that teacher educators share their expertise as practitioners, researchers, and theorists, making explicit what is often tacit and unspoken, when sharing knowledge, reflections, and actions (Beck, 2016; UNESCO, 2022). By enhancing open educational practices (OEPr), teacher educators may showcase what they know, and how they enact and embody the art and craft of teaching (Marzano, 2007). Teacher educators who model OEPr respond to Canada's Digital Charter: Trust in a Digital World (Innovation, Science and Economic Development Canada, 2023) and further the mission of the United Nations Educational, Scientific and Cultural Organization's (UNESCO) 2030 Global Sustainable Development Goals (SDG) for education (Montoya, 2018). Specifically, this research furthers the work toward SDG goal 4.c.1 by responding to the global need to substantially increase the number of qualified and trained teachers, as well support international cooperation for teacher training potentially through the sharing of OEPr (Montoya, 2018).

Research literature suggested a need for an intentional focus on media and digital literacies and technological competencies in teacher education (Falloon, 2020; Foulger et al., 2017). This post-intentional phenomenological research study responded to this need by examining moments, materials, and insights from the stories shared by teacher educators in faculties of education across Canada as they reveal media and digital skills, fluencies, competencies, and literacies in their OEPr. By studying the phenomenon of OEPr, insights are gained into how teacher educators seize opportunities to work through complex matters while applying technology resources. By actively “thinking out loud” through blogs, social media, and open scholarly publications, teacher educators share details of the *what, how,* and *why* they *do what they do*.

As revealed in this paper’s findings, the rationale and definition of terms relating to the research are outlined, and conceptual frameworks are identified, before sharing stories from the participants. Insights are provided in the discussion, followed by implications, recommendations, and a conclusion.

Defining Terminology

Understanding terminology is critical. A clarification of the term *practice* is offered since this research focussed on the *practices of practicing* in a teacher educator’s practice. Confusion can and does emerge from this polysemous term as it holds multiple meanings as both a noun (the thing we call a practice) and a verb (the actions we undertake as we practice). Complications occur when the thing is confused with the doing. This research examined how teacher educators practice their craft of teaching within an OEPr.

Teacher Education

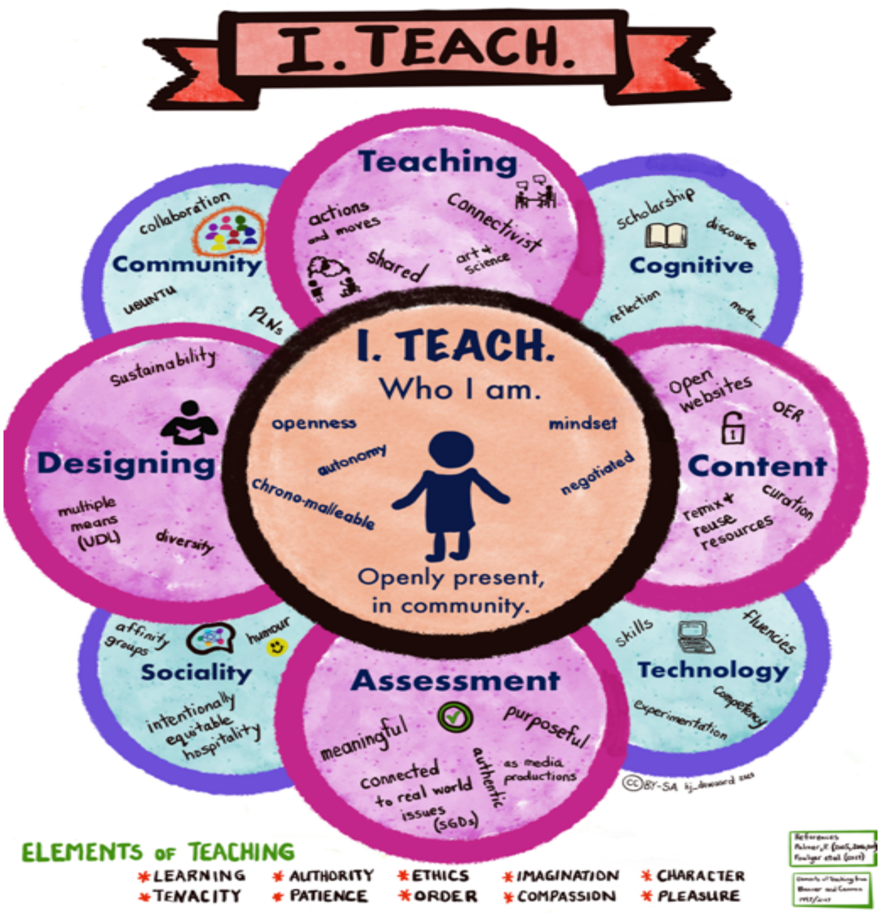
Education in Canada is a provincial mandate; thus, teacher education falls under provincial dictates and constraints. For purposes of clarity, initial teacher education refers to components in a faculty of education program of study that includes the compilation of courses focusing on preparing students to become teachers in the K-12 sector. Teacher educators and their students are required to bridge the significant differences in teaching and learning between K-12 and higher education. Additionally, technologies and digital resources used in the K-12 sector may not be available to the higher education environments where the learning occurs. This confusion across jurisdictions leaves digital skills, fluencies, and competencies within Canadian faculties of education in a complex tangle.

Open Educational Practices

For this research, the acronym OEPr was used to distinguish this concept from research into open pedagogies. This small shift in the commonly used nomenclature within the field of open education provides distinction and clarity (DeWaard, 2023). Definitions of OEPr vary, but for this research OEPr is considered as both external actions or events as well as internal qualities that are contextual, complex, and individual (Cronin, 2017). Open educational practices can include teaching designs, content, and assessment, but also technologies, sociality, community, and cognition (Figure 1). Because open educators use a variety of social media and web-based publication options, objects, and events, their OEPr may be integrated into course materials, referenced in teaching events, and remixed by others.

Figure 1

I Teach



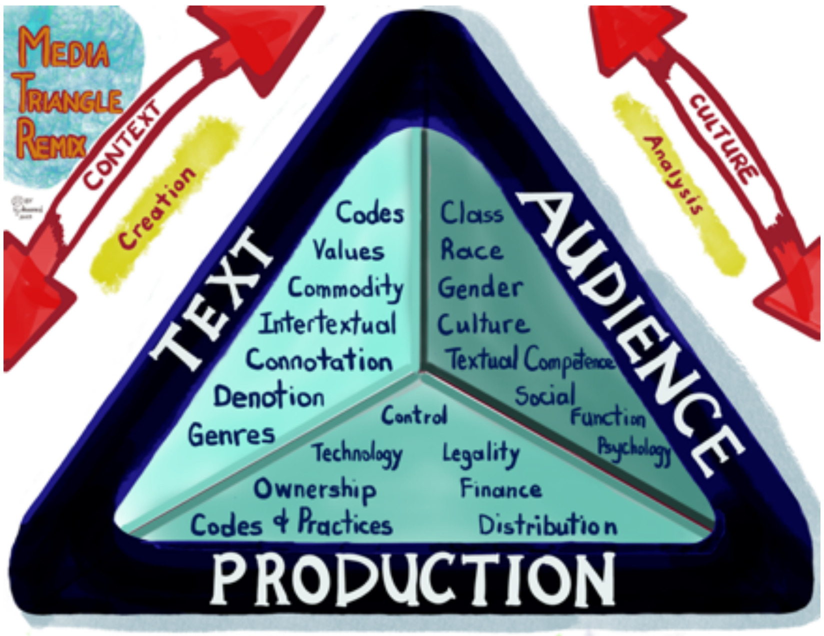
Note. Referencing Palmer (2017); Foulger et al. (2017); Banner and Cannon (2017). Created using Procreate on iPad. Published under CC BY DeWaard (2023).

Media Literacies

Defining media literacies includes actions of co-construction within social contexts, examining semantics relating to mediums used, understanding contextual media messages, challenging bias and dominant hierarchies, revealing purposes of media messages, and viewing media cultures as sites of struggle (Kellner & Share, 2019). Media literacies are shaped by an understanding of the key areas of text, production, and audience as framed in the remix of the media triangle (Association for Media Literacy, 2022) (Figure 2). For text production, media choices include codes, genres, and commodities. For media production, consideration is given to the tools, technologies, or design factors that shape the messages being communicated. When analyzing or creating media messages within faculty of education courses, consideration includes the audience through distribution factors, technological choices, and control of the production.

Figure 2

Media Triangle Remix



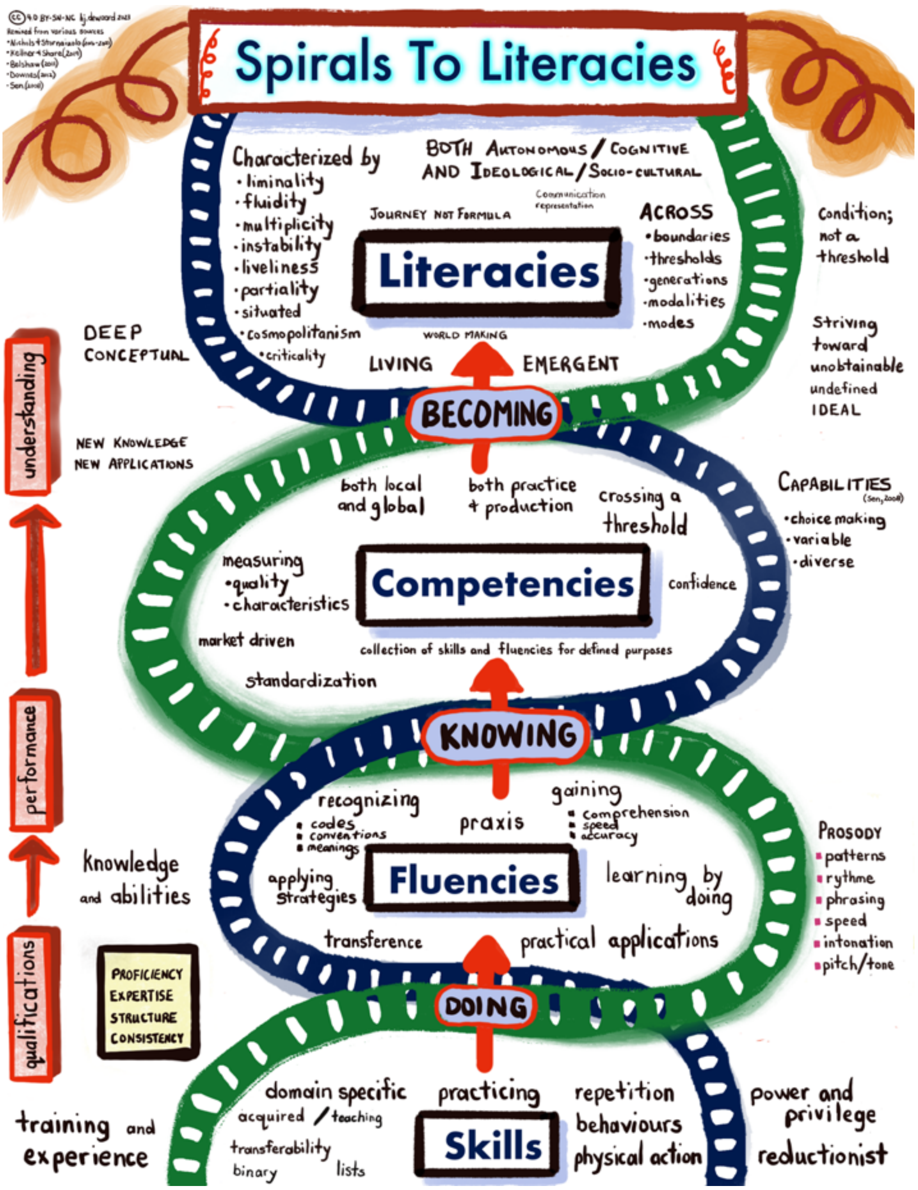
Note. Referencing Association for Media Literacy (2022). Created using Procreate on iPad. Published under CC BY DeWaard (2023).

Digital Literacies

Digital literacies are critical to the inclusion of technologies into teacher education course contexts. Digital literacies are framed by both the cognitive and social practices when using, understanding, and creating with digital technologies (Falloon, 2020; Stordy, 2015). For this research, digital literacies are composed of three areas of proficiency: "*the skills and ability to* use digital tools and applications; *the capacity to critically* understand digital media tools and content; and *the knowledge and expertise to* create and communicate with digital technology" (emphasis in original) (Hoechsmann & DeWaard, 2015, p. 8). By spiralling toward the ideal of digital literacies, teacher educators can acquire digital skills, fluencies, and competencies (Figure 3) that support their OEPr.

Figure 3

Spirals Toward Literacies



Note. Compiled and remixed from Belshaw (2011); Downes (2012); Hoechsmann and Poyntz (2017); Kellner and Share (2019); Nichols and Stornaiuolo (2019, 2021); Smith et al. (2018); Stornaiuolo and LaBlanc (2016); Stornaiuolo et al (2017). Published under CC BY-SA-NC DeWaard (2023).

Frameworks

This research is framed by a socio-constructivism epistemology and a post-intentional phenomenological approach. It also considers the phronesis/episteme dichotomy inherent in the design and delivery of faculty of education programs. The theoretical foundations of socio-cultural constructivist theories of learning originated with Dewey (1916), Vygotsky (Lowenthal & Muth, 2009; Roth & Lee, 2007), and Papert and Harel (1991). A socio-constructivist paradigm adopts a relativist ontology, suggesting there are many possible realities, and a subjectivist epistemology whereby the researcher and participant co-create shared understanding (Denzin & Lincoln, 2013). In this research, the understanding of lived experiences within an OEPr is constructed, action-oriented, acquired through collaborations in conversation, and generated through media/digital processes and productions.

The dichotomy between phronesis and episteme impacts this research as it delves into the understanding of what it means to practice a teaching practice *openly*. Underlying the shared stories of the participants' lived experiences are conceptual frameworks of theory-into-practice, practice-into-theory, and theory-and-practice (Russell et al., 2013). When exploring the media and digital literacies of teacher educators who model an OEPr, it is essential to consider the "epistemology of practice that takes fuller account of the competence practitioners sometimes display in situations of uncertainty, complexity, uniqueness, and conflict" (Russell et al., 2013, p. 15). Through sharing their OEPr, reflective practice, and teach-aloud activities, the tacit knowledge implicit within patterns of action of these teacher educators may reveal judgements, skills, and competencies (Russell et al., 2013). Both the theoretical foundations *and* practical experiences of the participants emerged. It is through practical applications of media and digital skills, fluencies, competencies, and literacies into an OEPr that theoretical understanding can be gained.

Frameworks from the literature relevant to media and digital literacies that supported this research included UNESCO's *Media and Information Literacy* framework (2013), *MediaSmarts* (n.d.), the *Digital Literacy* framework (Belshaw, 2011), the *Digital Literacy Competency Frameworks Analysis* (Martínez-Bravo et al., 2022), the *DigComp EDU* (Redecker, 2017), and the DQ Institute (n.d.). The open education framework *Practical Guidelines on Open Education for Academics* (Inamorato dos Santos, 2019) also informed the results.

Methodology

Phenomenological research aims to reveal and describe lived experiences in order to gain understanding of the meaning of a phenomena (Cilesiz, 2011). This post-intentional phenomenological research focuses on "richly describing the experiential essence of human experiences" (Tracy, 2020, p. 65) relating to the OEPr of teacher educators. Post-intentional phenomenology is distinguished from transcendental and interpretive theoretical approaches (Figure 4). As a research methodology, post-intentional phenomenology brings a fluid focus on human-technology relations by examining the ways technologies impact relationships between human beings and the world, thus shaping human interactions, relationships, and embodiment (Ihde, 2011). Following a post-intentional phenomenological approach, this research examined the lived experiences of teacher educators' relationality (lived relation), corporeality (lived body), spatiality (lived space), temporality (lived time), and materiality (lived things and technologies) (Vagle, 2018). The researched centred on the phenomenon of an OEPr.

Figure 4

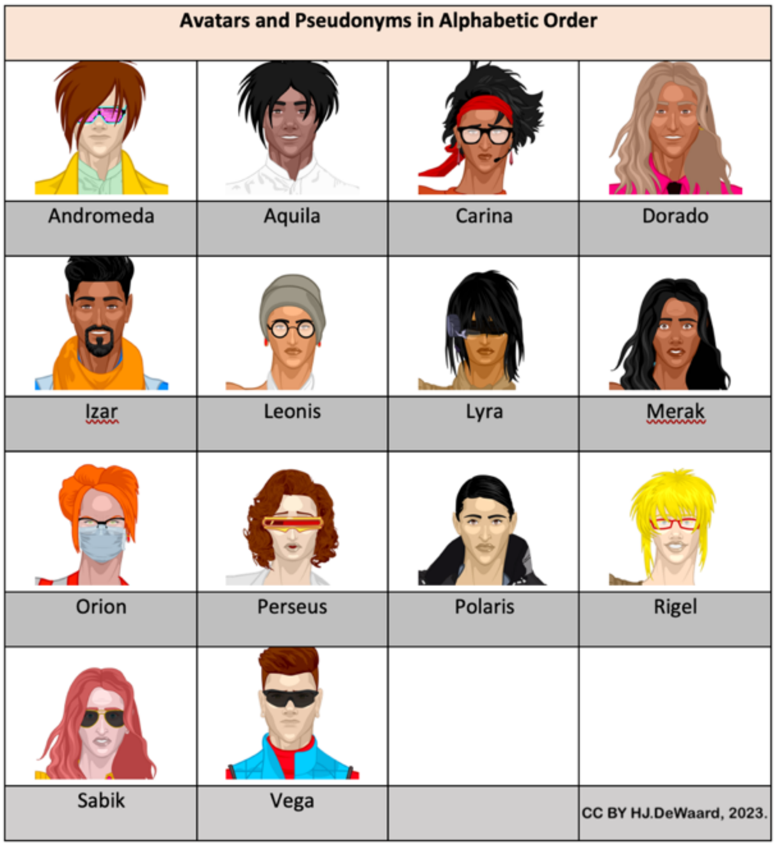
The Phenomenon of Phenomenology

Note. Remixed from Ihde (2015); Rocha (2015); Rosenberger and Verbeek (2015); Vagle (2018); Valentine et al. (2018); van Manen (2014). Published CC BY-SA-NC DeWaard (2023).

Through purposeful sampling, participants who met the established criteria were contacted. Once informed consents were received, and to ensure confidentiality, randomized avatars and names garnered from star charts were applied (Figure 5) to the 14 participants. Sources of digital information included social media activities, websites, blog posts, course syllabi, and curriculum vitae. The semi-structured and conversational 60-minute interviews followed guidelines outlined by Merriam and Tisdell (2015) and focused on the participants' lived experiences of media and digital literacies from within their OEPr. Digital artifacts were created by participants after the interviews as reflections of experiences with media and digital literacies. Once transcribed, the data was coded and analyzed using NVivo software to reveal facets that shaped insights. After several reviews of the data, specific elements crystallized into findings (DeWaard, 2023). The findings focus on the shared stories of OEPr relating to teacher educators' practices. These findings are not intended to be generalizable but are offered as potential practical models to shape media and digital literacies infused with technologies from a teacher educator's perspective.

Figure 5

Avatars and Pseudonyms



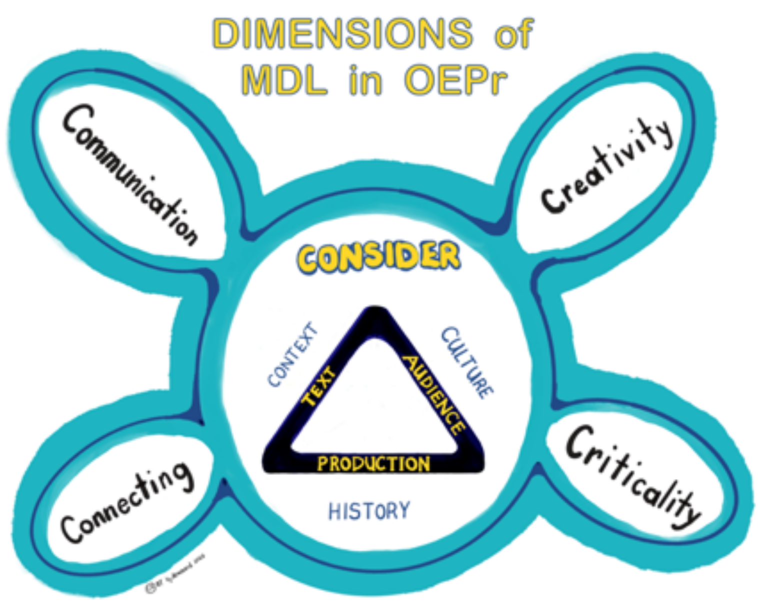
Note. Compiled and remixed from research design and findings. Published under CC BY-SA-NC DeWaard (2023). Anonymized names and images for the participants in this research.

Findings and Discussion

The research findings focus on how the participants managed to keep their eye on their OEPr within an unknown future in uncertain times when infusing media and digital literacies into their teaching, particularly when using technology. Since this research was conducted in the aftermath of COVID-19 constraints and periods of online-only instruction, pandemic related experiences emerged as a sub-plot within the stories. The findings revealed complex navigations and decisions with media and digital skills, fluencies, competencies, and literacies within an OEPr, as mediated through technological integrations. Four dimensions were generated from the shared stories. These include communication, creativity, connections, and criticality (Figure 6). The findings and discussion are merged to better understand how these four dimensions were integrated in the research findings and the literature. To distinguish participants from research literature, the names of participants are designated with bold and italic text.

Figure 6

Dimensions of Media and Digital Literacies (MDL) in Open Education Practice



Note. Compiled and remixed from research findings. Published under CC BY DeWaard (2023).

Communication

In the area of communication, participants mentioned risks and benefits, intended audience, and issues of access when communicating with technologies. Participant ***Merak*** considered the risk-benefit tensions that emerged when considering safety, security, privacy, and permissions: "*I guess my desire to have students live, sharing in the open in my course and finding there was a bit of tension for me in terms of protecting them, just making sure that they were feeling safe enough*". ***Orion's*** and ***Rigel's*** experiences with trolling (when others' online comments are intended to be negative or hurtful) and ***Aquila's*** experiences with catfishing (when personal images or information are used by others to create fictional or alternative online accounts) showed an awareness of the darker side of technology. Participants mentioned explicitly teaching students about password protection of pages and posts on a blog site, thus ensuring students had agency and control of permissions to sensitive or confidential information published to the web. These experiences modelled care and concern for both their own and students' data management skills.

When sharing communications as part of an OEPr, ***Vega*** wondered: "*I'm hired as an educational researcher, a theorist. I'm supposed to be working on behalf of Canadian citizens. So how can I create communication ecosystems so that they can access some of the work?*". For ***Rigel*** this suggested that "*the purpose that you're doing it is not just performative for the whole world that you actually are doing it because students will feel the value*". For ***Vega*** this meant recognizing audience: "*If we're talking about access, I think you need to recognize audiences you are trying to communicate with, and then how accessible in terms of having open access is what you're trying to communicate*". ***Lyra*** suggested keeping audience in mind when making critical decisions about "*what you're comfortable sharing and what you're not comfortable sharing*".

Communication included issues relating to access, specifically entry points and gateways, as well as an intentionality in sharing. ***Polaris*** suggested a consideration for using teaching resources that are "*visible you know, not behind paywalls" and their avoidance of using technologies "that require students to sign up*". For ***Andromeda*** and ***Merak*** this meant that learning opportunities were open to "*people outside of your class, outside of that specific group would also have access and it's something that you would allow people to share*". Seven participants reflected on how communication, particularly for their students, needed to extend beyond the physical classroom. Issues of access for three participants emerged when using languages other than English.

The findings from the communication dimension reflected the ubiquitous nature of using technology when sharing communications. One participant suggested that media framed the messages, and that digital was the mechanism for sharing communications. The medium, and the digital format of the technologies used, shaped the messages that were communicated and exerted influence over how messages were constructed and shared. Decisions about sharing course materials on open web-based locations was dependent on multiple factors such as the course topic, fluencies with web publication, time required, and supports available for course development and design.

As echoed in this research, digital competencies emphasize communication when educators incorporate "learning activities, assignments and assessments which require learners to effectively and responsibly use digital technologies for communication, collaboration and civic participation" (Redecker, 2017, p. 23). Young and Nichols (2017) suggested that "diversification of communication within teaching and learning practice gives students more choice and opportunity to interact with both their peers and teaching staff" (p. 345). This variation was evident as participants described using blogging as a means of shifting course communications into open digital spaces, using podcasts to deliver course content, and integrating video and image production into their communication strategies with students.

Participants' communications hinged on decisions to use both digital and analog domains. Continual negotiations between/among distribution of communications through public, private, and controlled digital spaces was evoked. Although technology was ubiquitous to the participants' practice, the digital was not magic. It permeated the way they practiced teaching and learning. The participants made strategic decisions as they attempted to answer questions such as: Will I share?; Why will I share?; With whom should I share?; Where will I share?; Is this good enough to share?; or How might sharing impact my digital persona? (Cronin, 2017).

Creativity

Creativity was mentioned by every participant and connected to multimodal productions and performance for themselves and their students. ***Izar*** wondered *"if you're thinking about open practices, you might be thinking about, you know, how can we enable creativity? How can we let people stand on their own and make choices around what they're learning and how it's represented?*" ***Izar*** developed teaching materials supported by fair dealing, Creative Commons, and open resources. For ***Dorado***, creativity meant resisting the use of exemplars in course materials or assignments and providing less choice since *"if you choose something that's really flexible, then there's more creativity inside of that narrow choice"*.

Creativity for many of the participants included accessing, using, and creating within multimodal digital and media productions that incorporated or apply text, icon, image, audio, video, and graphic formats. For ***Aquila*** this meant "*understanding how to convey messages, through media in different ways, not just print literacy … we have to be much more well-rounded"*. ***Andromeda*** and ***Rigel*** mentioned multimedia as an entry or gateway into learning, thus synergistically using "*what we need to use in order to learn*". For ***Polaris*** creativity with multimodal productions "*became a real opportunity into building my ability to create using digital tools, which then became the driving force for further deepening my media and digital literacies, which became more apparent and necessary as sharing became possible"*. It was through the active process of creating a learning object or designing a course using a variety of media, in concert with developing explicit instruction and critical questioning, that media and digital literacies impacted the participants' OEPr.

Creativity in OEPr for ***Sabik*** and ***Rigel*** included consideration of how students were given options to share their learning beyond the "*disposable assignment*", described by Wiley (2013) as those tasks such as essays or exams that add no value to the world since they are thrown away and forgotten once they are completed. ***Rigel*** provided choice as a gateway *"for students to become more open about how and where they share their learning"*. ***Aquila*** saw creative works, particularly remix, as a core element in their teaching: *"I don't have students create essays, I figured by the time they're in my course, they know how to do essays. So, we always explore media. For example, students reflect and create multimodal summaries of learning"*. Creativity included choice in how and why they shared, as suggested in ***Rigel***'s comment: "*sharing your process is a form of open pedagogy for me; I feel there's a spectrum of sharing more broadly and making it accessible for a broader audience is really helpful"*.

Creative production was not just for the purpose of sharing beyond a course. ***Perseus*** questioned "*when students create content that they share openly online (e.g., websites, digital artifacts, SM posts, accounts, channels) are their interests as learners served*?" The challenge in creative productions was ensuring authenticity in the process and products – the content, the conversations, the assignments, and the learning activities – and ensuring these meaningfully related to a course of study.

The findings suggested that creativity was an essential element of an OEPr and emerged from a flexible and technologically fluent mindset (Henriksen & Cain, 2020). This fluency in mindset was grounded in disciplinary knowledge, technological knowledge, an experimental disposition with technologies along with a "willingness to push students to consider and re-consider what they know" (Henriksen & Cain, 2020, p. 177). This included a readiness to imitate and remake media (Hobbs & Friesem, 2019), as modelled by ***Polaris*** in their digital artifact created using Twine (https://twinery.org/), or to integrate a design approach for a student blog hub for course assignments. Henriksen and Mishra (2015) suggested that teachers who actively cultivate a creative mindset in their teaching practices transfer these creative tendencies from outside, open pursuits and interests, into their teaching practices. This was evident when ***Andromeda*** and ***Lyra*** shared stories about creating an open Pressbook with their students.

Participants showcased that "students need to engage with issues of production, language, representation, and audiences to address how meaning operates in the electronic media" (Hoechsmann & Poyntz, 2017, p. 7). This was evidenced in ***Dorado's*** lived experiences with students creating assignments relevant to global and urban perspectives in education using Padlet technology and the lived experiences of participants with students who created digital portfolios.

Belshaw (2011) contended that creativity was a necessary component of literacy and suggested that reproduction and remix are creative acts. This was echoed by Hoechsmann (2019) who asserted that the "spark of originality, creativity and 'authorship' lies in the yoking together of already existing elements, often with some further innovation or addition" (p. 95). From the findings, one example that specifically points to this remix creativity in action was the story of ***Carina's*** work with teacher candidates and students in local schools to remix coding and computational thinking opportunities within a special project to design and program a robot to navigate on the moon.

Connections

Shared stories revealed how participants connected ideas, people, and teaching in ways that built on the shared learning of/with others, particularly with insights gained from COVID-related teaching experiences. Connections included opening up links to others in complimentary fields of study for themselves and their students, as exemplified by ***Aquila's*** comment: *"It's really about connecting with expertise in different ways and showing students that they can connect not just to databases and resources online but can connect to the people behind them"*. ***Aquila*** and ***Lyra*** mentioned that they reached out to authors of research papers to build on the ideas presented by these other scholars: *"I think we need that connection with experts, you know, or things that we know work and in different ideas, not the same ideas … as we already had"*. When knowledge sharing, ***Izar*** made efforts to *"try to make outputs open, try to make as much of the teaching as possible, open, because it can have effects that are interesting, if you make a connection with another educator"*.

Connections were shaped by building trusting relationships. ***Dorado*** mused:

> *I think that whether it's between teachers and students, or researchers and participants in online spaces with distant others that you may never ever see in person, I think that kind of relational work has to happen, especially if you're doing critical literacy work, because you've got to have a lot of trust.*

Additionally, ***Dorado*** reflected that relationship building required active listening along a continuum from short term contacts to deeper connections. For ***Aquila*** this linked back to experiences and relationships developed over time, where geographic locations mattered less and maintaining relationships mattered more: *"I guess the idea that we're better together, that our voices matter from any place that we can find, we can build closer relationships with people that we don't necessarily know, that's the strength of weak ties".* Meaningful connections in an OEPr are supported by digital technologies and media productions, both individual and collaborative.

From these findings, participants' stories reveal how humanizing teaching and learning practices engaged others ***through*** the screen rather than ***to*** the screen (Morris, 2020). For ***Vega***, this relationship work required *"unconditional hospitality"* and recognizing "*that when you're a guest in someone else's space, then there's certain roles and responsibilities. But also, when you're hosting a guest, there's roles or responsibilities. So that relationship between guests and hosts, it goes back and forth"*. ***Vega*** described unconditional hospitality as being attuned and deeply listening to others, being reciprocal, sharing accessibly, understanding the barriers preventing connections, and avoiding inflicting harm on others. Connectedness is described in how participants formed hybrid identities to exchange "needs, motivations, solve problems or to create new products/ideas" (Martínez-Bravo et al., 2022, p. 6).

Thestrup and Gislev (Mackenzie et al., 2022) suggested that acting globally and feeling connected required a mindset found on the playground. Such playful mindsets included "experimental, non-linear, immediate and multimodal digital literacy practices" linking to "content, tools of learning, contexts, peers, levels of challenge, time and place" (Tour, 2017, p. 15). This playful ethos was evident in the participants' stories as they uncovered connections from/to texts, self, and the world within nuanced and multiple layers of engagement, while maintaining a focus on their students as the primary audience. This was modelled in the use of course hashtags and through purposeful collaborations on productions with/for student learning such as ***Leonis***' connections to global contexts through video productions with immigrant students, and ***Andromeda*** and ***Izar's*** connections to the Global OER Graduate Network (GO-GN).

Participants' interactions through the screen were marked by a heightened awareness of endeavours to dismantle power dynamics, as reflected in the research literature (Couros & Hildebrandt, 2016; Mirra, 2019). Participants applied approaches within their OEPr to cultivate relationships and structure opportunities to build connections that included sharing, reuse, and remix of materials and methods to break down hierarchical structures and open connections with/for students. The shared stories included descriptions of active and sometimes playful engagements in course work, communities of practice, and networked learning.

Criticality

As suggested by Bell Hooks (2010), criticality requires thinking in action, interactive processes, becoming relentless interrogators, and keeping an open mind. Criticality for the participants and their students occurred in how they received and emitted information, as they constructed professional digital identities and circulated their learning into open digital spaces.

Perseus mentioned: "*I have the little open access symbol on my CV, and I put it beside every single publication on my CV; any of them that are open access, I ensure that that symbol is there*". Participants' stories included facing fears and accepting the risks of openly sharing as a teacher educator, as exemplified in ***Andromeda's*** comment: "*it's not just about I'm scared to share. It's I'm scared to share because of professional repercussions, which is very different*." Criticality was evident in experiences with their students as the participants supported teacher candidates to reveal their professional identities in open web-based spaces. Consideration for "*this practice of helping teachers to sort of grow into their digital public persona through, you know, open writing*" was mentioned by six participants.

Criticality was noted by ***Andromeda*** who mentioned sharing as "*a negotiation and co-design between an instructor and the student to support their learning pathway on their learning journey*". From ***Merak's*** experiences, criticality was an essential and core tenet "*because any instance in which we see technology as neutral as not having been socially constructed and not constructing us, I believe to be problematic*". ***Dorado*** wondered: "*I guess where the critical part comes, is partly about the tool, but really more about the content, right? And the kinds of ideas that are in there*." ***Leonis*** suggested: "*media literacy is more of critiquing things. I mean, it is supposed to be productive. But I don't think it's been all that productive. The digital allows you to take it into that productive space with a critical perspective*".

From these findings, criticality emerged through careful, collaborative, and informed critique of technologies, structures, and participation. Criticality explicitly included examination of their own practice and that of organizational decision-makers. Participants mentioned intentional actions to counter techno-deterministic educational technology narratives, particularly the notion of knowledge scarcity (Stewart, 2015). Similarly, ***Perseus*** mentioned resisting attentional economies with its focus on clicks and time on task.

Participants shared their intentional decisions to oppose the academic surveillance of students (Kuhn & Raffaghelli, 2022) and contested referencing students as consumers (Mirra et al., 2018), as evident in ***Perseus***' comments of technological architectures that embed market logics to perpetuate attentional economies and ***Rigel's*** questions about platform capitalism. For ***Izar*** and ***Orion*** this criticality included decisions relating to tools and technologies for the curation and aggregation of student work with a view toward technological agnosticism.

The criticality dimension included how OEPr contributed to the establishment or breaking of boundaries relating to identity and power structures (Koseoglu, 2017; Stewart, 2021), and criticality in data literacies and algorithmic bias (Nichols et al., 2021; Raffaghelli & Stewart, 2020). Criticality was evident as participants revealed how they grappled with ethical use, creation, and communication of media produced *with* digital technologies, but more worrisome were those productions *by* technologies which occurred with the advent of increasingly capable artificial intelligence software (Borenstein & Howard, 2021), particularly with large language models such as ChatGPT (Contact North, 2023). As mentioned by ***Aquila***, additional shifts in OEPr may emerge as the application of block-chain technologies impact educational practices (Privacy Technical Assistance Center, 2019). This reflects notions of criticality as a digital literacy since it "constitutes a great commitment to the construction of significant ecosystems and the development of an awareness and values connected with social and civic responsibility in a globalized world" (Martínez-Bravo et al., 2022, p. 11).

The findings suggest that criticality within an OEPr involves the creation of spaces for building knowledge that are grounded in the labour of marginalized communities. For Collier and Lohnes-Watulak (Mackenzie et al., 2022) this included interrogating where people in positions of power inadvertently or intentionally erase knowledge work created by others. This is of particular importance to Canadian teacher educators in order to address and respond to issues identified in the Calls to Action (The Truth and Reconciliation Commission, 2015). Opportunities to remix content and produce multimedia elements in courses in faculties of education may offer students a creative way to show what they know, thus "troubling the traditional definitions of academic authorship and knowledge…these new forms could validate understandings rooted in communities of colour, indigenous communities, and queer communities" (MacKenzie et al., 2022, p. 310). Opportunities for marginalized populations to share their stories speaks to how faculties of education may shape the way higher education addresses concerns of access, equity, indigeneity, diversity, and marginalization. This echoes how criticality is applied to expressions of social imaginaries, described as the shared collections of artefacts, images, and sounds constituting the representational milieu within which individuals give and receive communicated knowledge (Wallis & Rocha, 2022).

Implications and Recommendations

As teacher educators revise course designs in whatever technological, pedagogical, or content areas they teach, they adapt to new and everchanging dictates and evolving digital technologies. This research revealed the complex and complicated decisional and navigational options made by teacher educators when focusing on communication, connections, creativity, and criticality as primary elements within an openly shared educational practice.

This applies to not only their own practice – as they consider how to share their pedagogical expertise and tacit knowledge about subject matter, teaching strategies, or assessment practices – but also student learning within the course design. One example was ***Vega's*** navigations and decisions when using podcasting as a primary means of course content with/for students. Another example was ***Izar's***, ***Aquila's***, and ***Orion's*** efforts to provide students with an aggregated blog as a means of connecting and networking while engaging in course related content, pedagogies, and technologies.

Recommendations that emerge from the findings and discussions that are relevant for teacher educators when developing an OEPr, include:

- Encourage teacher educators to share their experiences with communication, connecting, creativity, and criticality openly. This can occur through open journal publications, posting pre-print manuscripts to personal or institutional blog sites, or sharing links or PDF files using academic repositories such as Academia and ResearchGate.
- As mentioned by ***Perseus***, use a Creative Commons license should be considered as the default condition, where and when this is permitted. This requires an examination and revision of institutional policies to support the open sharing of teaching and learning materials.
- Develop awareness of institutional policies relating to OEPr. It is suggested that although institutional policy may have guided participants' OEPr and data management strategies, it was a concern for student safety and security that ultimately shaped the communications about safety, security, privacy, and permissions for many in this research.
- Share openly through one or many digital and web-based technologies such as blogging, video productions, social media sites, and professional organization websites. As modelled by participants in this research, sharing expertise in teaching and learning can become a beacon of hope for others who struggle within other faculties and fields of study, particularly when unforeseen events such as a global pandemic impacts traditional teaching and learning structures.

- Promote intentionality as a necessary condition for OEPr to emerge. ***Perseus'*** lived experiences of OEPr highlighted the need for humanizing the learning experiences for students from a caring stance, one that encompasses compassion, empathy, fairness, honesty, openness, and respect for human dignity. This shared story provides insight into perspectives on relationships with students that addresses power differentials between the perceived or real hierarchical positions between students and educators.
- Develop a flexible and technologically fluent (Henriksen & Cain, 2020), self-reflective mindset. This shift in mindset, when shared openly, provides a playful approach to teaching and learning that benefits both the teacher educator and their students.
- Connect to communities and build networks. Since teaching and learning should be a social event, ensuring that teacher educators are connected to influential others can support the continual development of skills, fluencies, competencies, and literacies. As connections grow, new networks may be revealed.

Conclusion

This research identified the need for teacher educators to critically examine and share their teaching and learning expertise with others in local, national, and global contexts. A teacher educator's OEPr can model and respond to current calls in national and global spaces and places for shared and collaborative teaching materials and practices from teacher education programs around the world (UNESCO, 2023). Infusing media and digital literacies into this OEPr, by focusing efforts on the key dimensions of communication, creativity, connections, and criticality, can better support the complex and complicated navigations teacher educators need to manage within an OEPr in current faculty of education instructional practices, and thus become trusted voices and exemplary models for others to follow.

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ePortfolios: A 360-Degree Approach to Assessment in Teacher Education

Les portfolios numériques : une approche à 360 degrés de l'évaluation dans la formation des enseignants

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Abstract

ePortfolios are increasingly being used for teaching, assessing, and supporting students' learning in higher education. With COVID-19 having forced many higher education institutions to move their education services and teaching to online spaces, ePortfolios have become more relevant in the assessment process as they are web-based. This self-study examines how ePortfolios are being used to support assessment practices in a South African and a Canadian teacher education program. Data comprised critical dialogue, notes, reflections, and conversations with students enrolled in both teacher education programs. Findings suggest that students use ePortfolios to integrate self, peer, and teacher/ expert feedback, which results in a 360-degree approach to assessment.

Keywords: assessment, ePortfolio, online learning, teacher education

Résumé

Les portfolios numériques sont de plus en plus utilisés pour enseigner, évaluer et faciliter l'apprentissage des étudiants dans l'enseignement supérieur. Lorsque la pandémie de COVID-19 a contraint de nombreux établissements d'enseignement supérieur à offrir leurs services éducatifs et leur enseignement en ligne, les portfolios numériques sont devenus essentiels dans le processus d'évaluation puisqu'ils étaient accessibles sur le Web. Cette étude de cas se penche sur la manière dont les portfolios numériques sont utilisés pour améliorer les pratiques d'évaluation dans le cadre de deux programmes de formation des enseignants, en Afrique du Sud et au Canada. Les données comprennent un dialogue à visée critique, des notes, des réflexions et des conversations avec des étudiants inscrits dans deux programmes de formation d'enseignants. Les résultats suggèrent que les étudiants utilisent les portfolios numériques pour intégrer leurs propres commentaires, ceux de leurs pairs et ceux des enseignants ou des experts. Il en résulte une approche à 360 degrés de l'évaluation.

Mots-clés : évaluation, portfolio numérique, apprentissage en ligne, formation des enseignants

Introduction

ePortfolios are increasingly being used for teaching, assessing, and supporting students' learning in higher education, especially in the field of teacher education (Cahill et al., 2022). With COVID-19 having forced many higher education institutions to move their education services and teaching to online spaces, ePortfolios have become more relevant as they are web-based and can be used to assess and support students' learning in various educational contexts.

Like many concepts in education, a variety of definitions of ePortfolios are found in literature. As ePortfolios became more widespread, Farrell (2020) argues that "educators began to articulate, theorise and develop the concept of electronic portfolio assessment in higher education" (p. 292). Most often, the definitions of ePortfolios include the functions of ePortfolios, which include storage, reflection, documentation, collaboration, showcase, and assessment (Farrell, 2020).

McLoughlin and Lee (2009) define an ePortfolio as an electronic collection comprising self-assembled evidence demonstrating a learner's knowledge, skills, and abilities, including learner-generated artifacts in multiple media forms that showcase both the products and processes of learning. An ePortfolio is also defined by Hallam et al. (2008) as an evolving electronic/online resource that acts to record, store, and archive the artefacts of learning and reflection for an individual learner. In essence, an ePortfolio is a digital space for teaching and learning which supports reflective, personalised, and collaborative learning. This is a virtual environment that allows for the purposeful presentation and reflection on evidence of learning through a collection of various multimedia artefacts linked to the learning outcomes.

ePortfolios are digital tools that serve as authentic formative assessments. They offer students the opportunity to integrate learning across stages, showcase learning artifacts, record reflective learning processes, and receive regular feedback for developmental purposes (Yang et al., 2015). A typical learning ePortfolio may include both academic materials and personal profiles of students. This becomes "more than a product, a simple repository of artefacts; it becomes a process of reflection, of organizing, prioritizing, analysing, and communicating one's work and its value, which may prompt insights and goals" (Corley & Zubizarreta, 2012, p. 64).

The term "assessment" in higher education often conjures different sentiments and emotions. From a teacher's perspective, Ramsden (2003) states that assessment involves "getting to know our students and the quality of their learning" (p. 180). Conrad and Openo (2018) suggest that assessment fundamentally shapes learning approaches and reveals the educational experience's qualitative nature. Yet when students in a teacher education program were asked to use one word to describe their perceptions of assessment, the four most common words were *fear*, *stress*, *anxiety*, and *judgment* (Vaughan, 2013).

This disconnect between teacher and student perceptions regarding assessment is a serious issue, especially since several educational researchers have clearly linked student approaches to learning with the design and associated feedback of an assessment activity (Biggs, 1998; Hedberg & Corrent-Agostinho, 1999; Marton & Saljo, 1984; Ramsden, 2003; Thistlethwaite, 2006). For example, standardized tests with minimal feedback can lead to memorization and a surface approach to learning; in contrast, ePortfolios can encourage dialogue, richer forms of feedback, and deeper modes of learning (Penny Light, 2016). In addition, a report by the International Commission on the Futures of Education (2021) advocates that assessment needs to evolve from a mode of compliance to a process of shared goal setting, which leads to growth. This is particularly important in a teacher education program where teacher candidates develop their professional identity and ability to provide meaningful assessment for K-12 students.

This focus on development is closely aligned with some Indigenous perspectives on assessment. Claypool and Preston (2011) state that Euro-American-centric assessment practices focus on written quizzes, tests, and exams, which primarily promote cognitive development via rational, linear, and accountable activities. They suggest that this approach to assessment is focused largely on meeting curricular outcomes, and it tends to neglect the physical, emotional, and spiritual domains of students. From an Indigenous perspective, Marule (2012) suggests that effective assessment utilizes practices that include the cognitive domain but focus equally on physical, emotional, intellectual, and spiritual growth.

The purpose of this self-study was to investigate how ePortfolios are being used to support assessment practices in a South African and a Canadian teacher education program.

Background Literature

Poole et al. (2018) point out the challenges and supports regarding integrating ePortfolios in education, emphasizing the formative assessment aspects and the collaborative discourse between teachers and students. These include equity of broadband access coupled with the disconnect between ePortfolios and the curriculum that must both be addressed before ePortfolios become a common feature of developing countries' educational landscapes. Harver et al. (2019) argue that support services and faculty development are the best tools to combat the challenges of adopting ePortfolios.

However, the implementation of ePortfolios has been found to have many benefits, including facilitating reflection, self-assessment, and professional development among teacher education students (Farrell & Seery, 2019; Hauge, 2021). Slepcevic-Zach and Stock (2018) highlight the influential role of ePortfolios as a tool for self-reflection. Furthermore, research indicates that ePortfolios have been employed in teacher education programs for various goals, including assessment, teacher development, and support for placement experiences (Farrell et al., 2021). ePortfolios for formative assessment are centred on a “collaborative, continuous discourse between teacher and student” (EUfolio, 2015). In a South African study, Van Wyk (2017) explored student teachers' views on ePortfolios as an empowering tool to enhance self-directed learning in an online teacher education course, emphasizing the use of ePortfolios to enhance personal growth, professional development, and to produce evidence for daily representations of teaching practice.

Haralabous and Darra (2018) explored the correlation between ePortfolios and student self-evaluation and alternative assessment in elementary education, focussing on the trends and viewpoints of primary school teachers relating to the "implementation of the ePortfolio as an alternative form of student assessment and as a tool for self-assessment by students" (p. 80). However, the overwhelming majority of these teachers state that they have little or no knowledge of ePortfolios (Haralabous & Darra, 2018; Modise & Mudau, 2023). Before advances can be made in ePortfolio integration into education, there needs to be a clearer understanding of the goal and function of ePortfolios as a tool for achieving learning outcomes (Modise & Mudau, 2023; Poole et al., 2018).

ePortfolios have been used to support assessment practices in South African and Canadian teacher education programs. Farrell et al. (2021) emphasize the evolution of ePortfolio assessment from a modular to a programmatic approach and as a capstone culminating experience at the end of a degree within the education landscape in Ireland. Farrell et al. (2021) found that Irish educators primarily utilize ePortfolios with their students for assessment, reflection, placement support, and developing employable skills. They further indicate that the implementation and adoption the ePortfolio approach by Irish higher education institutions has been quite uneven, with most institutions reporting to be at the early stages of adoption. In South Africa and many developing countries, higher education contexts are no different, where online teaching is generally still in its infancy (Ng'ambi et al., 2016).

Theoretical Frameworks

This study is anchored in the following theoretical perspectives:

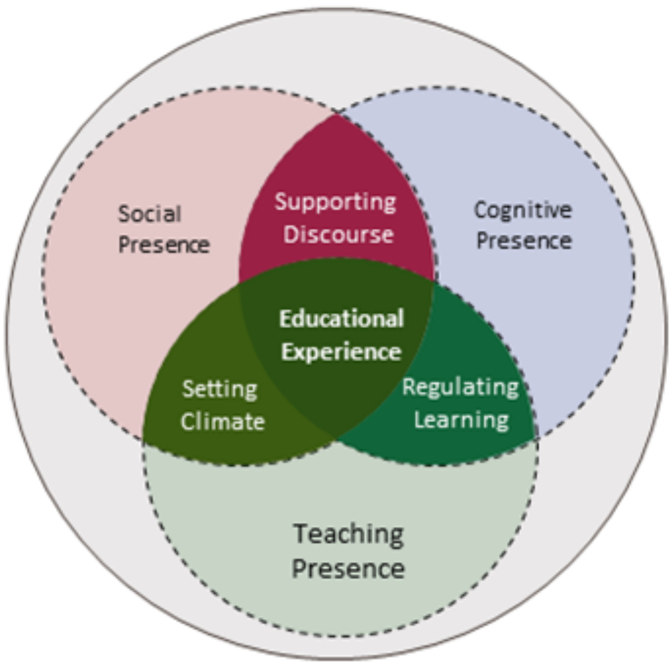
1. Community of inquiry (Garrison, 2017).
2. Self-study in teacher education (Hauge, 2021).

“An educational community of inquiry is a group of individuals who engage collaboratively in purposeful critical discourse and reflection to construct personal meaning and confirm mutual understanding” (Garrison et al., 2024, “CoI Framework” section). The Community of Inquiry (CoI) theoretical framework was derived from higher education literature. It is a generic educational model applicable to various educational contexts and modes of communication. Although it has been used to study and design online educational experiences, it is just as applicable to collaborative and meaningful face-to-face inquiry. For this reason, it is effective in designing digital technology approaches to assessment (Garrison & Vaughan, 2008; Vaughan et al., 2023).

The three key elements or dimensions of the CoI framework are social, cognitive, and teaching presence (Figure 1). It is at the convergence of these three mutually reinforcing elements that a collaborative constructivist educational experience is realized. Social presence creates an environment for trust, open communication, and group cohesion. Cognitive presence is “the extent to which learners can construct and confirm meaning through sustained reflection and discourse in a critical community of inquiry” (Garrison et al., 2001, p. 11). It has been operationalized through the developmental phases of inquiry: triggering event, exploration, integration, and resolution. The third and cohesive element, teaching presence, is associated with the design, facilitation, and direction of a community of inquiry. It is the unifying force that brings together the social and cognitive processes directed to personally meaningful and educationally worthwhile outcomes. Research studies have demonstrated that a high level of teaching presence is a good predictor of student success and satisfaction in a blended or online course (Shea et al., 2010; Torras & Mayordomo, 2011; Zhang et al., 2016; Zhao & Sullivan, 2017).

Figure 1

Community of Inquiry Framework (Garrison, 2017)



Hauge (2021) indicates that self-study in teacher education is the study of oneself and one's own practice and involves a moral commitment to improving this practice. A dedicated teacher, according to Celik and Yildiz (2017), is never content with what they already have and is constantly looking for new concepts and methods to help their students. Additionally, they argue that a committed teacher possesses passion and enthusiasm for both teaching and learning and that this devotion directly affects the students' academic performance and personal growth. The committed teacher may feel morally obligated to continuously improve their knowledge and skills, thereby improving the teaching practice. Teaching and learning with ePortfolios require that both students and teachers actively reflect on their journeys and thus continuously look for ways to enhance their teaching and/or learning.

Bullough and Pinnegar (2004) add that self-study can be used in relation to teaching and research on practice with the intention of the better understanding of both oneself as a teacher educator, and the development of knowledge related to these factors. Self-study refers to teacher educators who intentionally and systematically examine their practice to improve it, based on a deeper understanding of the practices and the contexts where the practice takes place (Vanassche & Keltcherman, 2015). Such an approach to self-study can be characterized as a specific form of action research (Hauge, 2021). ePortfolios have been dubbed effective self-reflective tools by educational researchers (Bodle et al., 2017; Slepcevic-Zach & Stock, 2018). They also play a dual role in developing self-directed learning for students (Modise & Mudau, 2023) while at the same time promoting collaborative learning (Buchholtz et al., 2018). The presence of other students and the instructors in an online learning scenario represents the opportunity for informal learning through social learning, peer learning, and formal learning through interaction with the instructor. Therefore, these two theories are well-placed to guide this study and to help unpack how the 360-degree approach to assessment can be applied in teacher education.

Methods

This section presents the study's research design, approaches, and methods used to generate and analyze data. The study is a case study design involving a self-study between two researchers in South African and Canadian universities. Our paper is situated within the interpretivist paradigm following a qualitative approach. Although the interpretive paradigm is not a dominant model of research, it is gaining considerable influence (Thanh & Thanh, 2015) because it can accommodate multiple perspectives and versions of truths (Alharahsheh & Pius, 2020; Pervin & Mokhtar, 2022; Thanh & Thanh, 2015).

Study Context

The teacher education programs at the University of South Africa (UNISA) and Mount Royal University were the focus of this self-study. UNISA is a comprehensive, open, distance e-learning university (CODEL) with 370,000 active students. As a CODEL university, UNISA offers students flexibility in choosing when, where, and how they study. The College of Education is responsible for the initial professional education and training of close to 50% of all teachers in South Africa (UNISA, 2023). The college employs various teaching and assessment tools and strategies, including educational technology, to train and prepare well-rounded student teachers in the Bachelor of Education (B.Ed.) and Postgraduate Certificate in Education programs.

Although all teaching, learning, and support activities are carried out on the university's learning management system, lecturers choose from an array of strategies, tools, and platforms to deliver the modules that they are responsible for. ePortfolios are one of the tools available to lecturers as an alternative assessment strategy (Van Wyk, 2017) and to support students' deeper learning experiences (Modise, 2021). According to Mudau and Modise (2022), ePortfolios are still a relatively new trend in developing nations; however, they are quickly evolving into an alternate teaching and learning tool for online and remote learning.

Mount Royal University is a four-year undergraduate institution located in Calgary, Alberta, Canada. This B.Ed. program was launched in the fall of 2001. Faculty and teacher candidates involved in this B.Ed. program have expressed increasing frustration with the provincial assessment framework that relies heavily on standardized testing with limited to no feedback for the learners. They have observed that local school boards have recently begun to develop an ePortfolio process to foster an increase in feedback and to encourage deeper learning modes (Calgary Board of Education, 2023).

These online learning plans allow students to take ownership of the documentation and goal setting for their own growth and development throughout their kindergarten to grade 12 educational journeys.

In order to help the Canadian teacher candidates to be "experientially" prepared for this type of learning environment, they are now required to design, organize, facilitate, and direct their own online professional learning plan (ePortfolio) throughout the entire four years of the B.Ed. program. The purpose of this learning plan is for teacher candidates to document and articulate professional growth and development related to the B.Ed. program competencies: planning, facilitation, assessment, inclusive environment, and professional roles and responsibilities. An example of a teacher candidate's ePortfolio can be accessed via this weblink: https://sites.google.com/mtroyal.ca/ryliekochsportfolio.

Both these Canadian and South African universities employ ePortfolio spaces for teacher candidates to develop and communicate self-understanding and create learning goals and strategies that will allow them to be most successful in their future teaching practice (Johnsen, 2012).

Data Collection

Aligned with key characteristics of self-study, our work was self-initiated (Hauge, 2021; LaBoskey, 2004) and involved reflecting on our personal and professional practice through ongoing and open dialogue (Samaras & Freese, 2009). This self-study involved two faculty members: one at the University of South Africa and one at Mount Royal University. We worked as a pair of critical friends (Dinkelman, 2003; LaBoskey, 2004), virtually meeting on a regular basis to discuss the relationship between ePortfolios and assessment practices in our teacher education programs. Furthermore, as self-study should "not only be of significance to the person who is conducting the study, but also of importance for creating meaning and contribute to increased understanding and knowledge for other teacher educators" (Hauge, 2021, p. 2), we were looking for implications beyond our own context and how other teacher education programs might consider using ePortfolios to support authentic approaches to assessment. Our data collection consisted of critical dialogue, notes, and reflections from our virtual meetings (Guilfoyle et al., 2004) and our conversations with teacher candidates (Fletcher et al., 2016).

Data Analysis

Data was analysed using content analysis. Qualitative content analysis is defined by Hsieh and Shannon (2005) as "a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" (p. 1278). Zhang and Wildemuth (2009) argue that content analysis emphasizes an integrated view of texts and their specific contexts, which is essential when dealing with case study research. Content analysis also makes it manageable for more than one author to simultaneously work on the same data and ensure the quality of data analysis is adhered to. Through systematic classification of data coding, key patterns in the data were discussed between the authors, and continuous member-checking was done to ensure the trustworthiness and validity of observations and interpretations (Lyons & LaBoskey, 2002). The key observations are reported in the Findings section.

Findings and Discussion

Our findings suggest that teacher candidates use their ePortfolios to receive and provide assessment feedback from a variety of sources, which includes self, peer, and teacher/experts.

Alverno College defines self-assessment feedback as “the ability of students to observe, analyze, and judge their own performances on the basis of criteria and to determine how they can improve it” (Allen, 2016, p. 4). This assessment process is often referred to as metacognition, or “thinking about one’s own thinking” (Costa, 1985, p. xi). Our observations and conversations with students in our teacher education programs suggest that they are using their ePortfolios to self-assess their growth and development related to course and program competencies. For example, students are required to set their own learning goals at the beginning of a semester or field experience and then document their progress towards achieving these goals. These goals must also be aligned to the course learning goals and objectives. Our experience suggests that students have limited prior experience with goal setting and thus require guidance and support in this process. We recommend using the SMART (specific, measurable, achievable, relevant, and timely) goal approach (Bjerke & Renger, 2017).

The Foundation Coalition (2002) indicates that peer assessment allows students to provide feedback to other students (i.e., their peers). In our teacher education programs, we utilize the concept of critical friends. A critical friend is a trusted person who asks provocative questions, provides data to be examined through another lens, and offers critiques of a person’s work as a friend (Lambrev & Cruz, 2021). A critical friend takes the time to understand fully the context of the work presented and the outcomes toward which the person or group is working. The friend is an advocate for the success of that work (Costa & Kallick, 1993). Depending on the context, students in our programs are either assigned or self-select a critical friend in a course or field experience. They then use their ePortfolios to provide peer feedback and support with course assignments and personal learning goals. It is a requirement for each student to have a critical friend and be a critical friend to another student. In this way, students are the receivers of constructive peer feedback and willing participants. This interaction also provides a platform for lifelong learning (Sobko & Brown, 2019).

In previous studies (Vaughan, 2013, 2014), teacher candidates identified several challenges with regards to providing peer feedback. First, several teacher candidates expressed concern about their lack of experience with peer assessment. They strongly recommended that instructors should “provide guidance and a class orientation on how to give each other meaningful feedback.” Another teacher candidate suggested that there should be “opportunities for both oral and written feedback.” He thought that ePortfolios were being used primarily to provide written peer feedback and that teacher candidates should also be learning how to provide oral feedback to each other. This comment was echoed by a teacher candidate who suggested that instructors should “provide class time to begin and conclude peer assessment activities.” She believed that this combination of face-to-face and online interaction would help to build trust and accountability for the peer feedback process.

Teacher assessment practices in higher education are often limited to high-stakes summative assessment activities such as mid-term and final examinations (Boud, 2000). The role of a teacher should be to provide ongoing and meaningful assessment feedback in order to help students develop the necessary metacognitive skills and strategies to take responsibility for their learning. Our experience suggests that ePortfolios allow teachers and experts (e.g., mentor or cooperating teachers in field placements) to provide ongoing formative feedback rather than just summative assessment. For example, faculty members in our teacher education programs use ePortfolios to provide students with formative assessment feedback at checkpoints or milestones for individual or group projects. This allows students to receive teacher feedback throughout the process of completing an assignment rather than just focusing on summative assessment feedback for the final product.

However, this active communication between the teacher and learners proves challenging in large classes such as at UNISA, which deals with large student numbers in a class. The use of e-tutors and teaching assistants, therefore, becomes important in supporting students further and managing online classrooms (Adams & Linschinger, 2019; Molotsi & Goosen, 2019).

Although some students may feel that they are not qualified to give feedback on their work, as seen above, some students appreciate feedback from their peers. This research shows that ePortfolios enable multiple sources of assessment feedback. For example, one student commented, "I use self-reflection for checking my work and ensuring I have everything I require for the assignment. I use peer review for a different perspective on my work, and I use instructor feedback to understand how I could improve my work." Another student stated that "self-reflection shows me what I like about my work and what needs to be improved, peer feedback provided me with comments on what could be done better, and then instructor feedback gives me ideas on how the assignment can be fixed up to get a better mark."

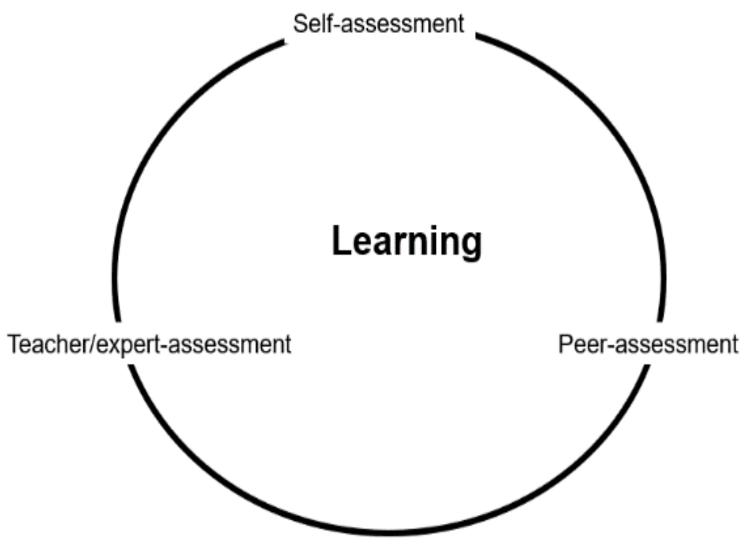
This study has revealed how students in our teacher education programs use ePortfolios to receive assessment feedback from multiple sources. We are discovering that students are using the digital technologies embedded in their ePortfolios to provide themselves with a 360-degree approach to assessment (Figure 2). A 360-degree approach to assessment acknowledges the three significant assessment affordances in ePortfolios, i.e., self-assessment, peer assessment, and teacher/expert assessment. The teacher/expect can be the module lecturer, e-tutor, teaching assistant, external markers and/or moderators. All these put the student at the centre of the learning process within the ePortfolio environment, enabling a holistic assessment and learning experience (Sobko & Brown, 2019).

Teacher/expert assessment feedback on students' growth and development focuses on formative feedback. The essence of the 360-degree approach to ePortfolios is that assessment is designed to be continuous and all-round, allowing each student to receive formal and informal assessments on their work.

Students use digital rubrics and blogs (online journals) to provide themselves with self-reflection and feedback on their course and field experience assignments. They then receive further feedback on their assignments from their peers through collaborative technologies such as Google Docs (2023). Finally, faculty members and in some cases external experts such as mentor or cooperating teachers are reviewing the students' ePortfolios and using video technologies to observe student performance, diagnose student misconceptions, and provide additional formative assessment feedback.

Figure 2

A 360-degree Approach to Assessment



Note. Figure created by the authors.

An international call for a greater focus on assessment *for* learning, rather than on assessment for *just* measurement and accountability of student performance is well documented in the educational research literature (Yeh, 2009). The use of digital technologies to support an increased focus on formative assessment practices may lead to Hattie's (2009) vision of a visible teaching and learning framework where "teachers SEE learning through the eyes of their students and students SEE themselves as their own teachers" (p. 238). A 360-degree approach to ePortfolio assessment emphasizes the importance of students learning to integrate self, peer, and teacher/expert assessment for their growth and development as teacher candidates. This approach recognizes the knowledge teachers and students bring to learning interactions, and it acknowledges how new knowledge and understandings can grow from shared learning experiences. The three types of assessments within the 360-degree ePortfolio space interact similarly to the community of inquiry framework (Garrison, 2017) to create a meaningful educational experience for all learners.

An ePortfolio assessment process also helps students develop their professional teaching identities, which may include physical, emotional, intellectual, and even spiritual domains (Torres & McKinley, 2023). Blair (2017) suggests that ePortfolios communicate not just a body of work but also a teacher candidate's evolving identity. When a teacher candidate assembles textual artifacts that tell a story of their learning through an ePortfolio, they are also assembling an identity, a particular way of being recognized in a certain social context (Gee, 2014; Kalmbach, 2017; Yancey, 2014). The current promise of ePortfolios, according to scholars like Rhodes et al. (2014), may be their capacity to help students transfer their learning by (re)negotiating identities assembled in the moment. An example of how the ePortfolio process helped a teacher candidate learn about her Canadian Metis identity can be accessed by this weblink: https://sites.google.com/mtroyal.ca/jaidenhourie/

As Hattie (2009) argues, visible teaching and learning happen when teachers see learning through the eyes of their students and when students see themselves as their teachers. ePortfolios further help create a collaborative online learning environment where teachers not only build a community (Garrison, 2017) and are self-determined (Hauge, 2021) but can also become co-teachers, thus co-creators of knowledge, in a connected world.

Conclusion

This study has revealed how students in our teacher education programs use ePortfolios to receive assessment feedback from multiple sources. ePortfolios are versatile tools that can be used in various contexts. A 360-degree approach to assessment in ePortfolios bringing a balance within the teacher education environment. Like a three-legged pot, in this approach, each leg represents an essential building block of authentic assessment in ePortfolios. As with the community of inquiry (Garrison, 2017), the goal is to afford learners and teachers a meaningful educational experience and an important lifelong learning opportunity. Within the digital era in which education operates, tools such as ePortfolios depend highly on various smart technologies. A further study on what kind of embedded digital technologies (i.e., video, audio, images) are used by learners and teachers in ePortfolios and how these impact the use of ePortfolios in teaching and learning may bring interesting findings to light.

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Preparing Educators to Teach and Create With Generative Artificial Intelligence

Préparer les éducateurs à enseigner et à créer avec l'intelligence artificielle générative

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Abstract

Teachers skilled in using generative artificial intelligence (GAI) have advantages in terms of increased productivity and augmented instructional capabilities. Alongside the rapid advancement of GAI, teachers require authentic learning opportunities to build the confidence and expertise necessary for engaging with these technologies creatively and responsibly. This article provides an illustrative case of preparing preservice and in-service teachers with the knowledge, skills, and mindsets to teach and create with GAI. Using a self-study method to investigate professional practices, we analyzed the curriculum, instruction, and assessment in an upper-level undergraduate course in multimedia design and production. Thirty-five teachers engaged in experiential activities focussed on developing artificial intelligence (AI) literacy, alongside a collaborative assignment to co-author an open-access textbook, *Teaching and Creating With Generative Artificial Intelligence*. To support equitable and inclusive access to the educational benefits offered by AI, the Student Artificial Intelligence Literacy (SAIL) framework was developed. SAIL facilitates student AI literacy through curriculum engagement and three distinct types of interactions: cognitive, socio-emotional, and instructor-guided. Building on lessons learned from the COVID-19 pandemic regarding the issues with technology training for teachers in Canada, five recommendations are offered to facilitate the meaningful integration of AI literacy in teacher education programs.

Keywords: AI education, AI literacy, generative AI, instructional design, teacher education

Résumé

Les enseignants qui maîtrisent l'intelligence artificielle générative (IAG) voient leur productivité et leurs capacités d'enseignement augmenter. En cette période d'évolution rapide de l'IAG, il est nécessaire d'offrir aux enseignants de réelles possibilités d'apprentissage en ce sens afin qu'ils acquièrent la confiance et l'expertise nécessaires à l'utilisation créative et réfléchie de ces technologies. Cet article présente un cas de figure illustrant l'acquisition par des enseignants en formation initiale et en poste de connaissances, de compétences et de l'état d'esprit nécessaires pour enseigner et créer à partir des outils d'intelligence artificielle. Nous avons analysé le programme ainsi que le type d'enseignement et d'évaluation d'un cours de premier cycle en conception et production multimédia, avec l'objectif d'étudier les pratiques professionnelles à partir d'une méthode d'auto-évaluation. Trente-cinq enseignants ont participé à des activités d'apprentissage par l'expérience axées sur le développement d'une culture de l'intelligence artificielle (IA), parallèlement à une collaboration en vue de la rédaction d'un manuel en libre accès, intitulé *Teaching and Creating With Generative Artificial Intelligence* (Enseigner et créer avec l'intelligence artificielle générative). Le cadre SAIL (*Student Artificial Intelligence Literacy*) a été créé pour favoriser un accès équitable et inclusif aux avantages éducatifs offerts par l'IA. SAIL facilite l'apprentissage de l'intelligence artificielle grâce à une implication dans le programme d'études et à trois types d'interactions distinctes : cognitive, socioémotionnelle et guidée par l'enseignant. À partir des leçons tirées de la pandémie de COVID-19 concernant les problèmes de formation à la technologie des enseignants au Canada, cinq recommandations sont proposées pour faciliter l'intégration réelle de la connaissance de l'IA dans les programmes de formation des enseignants.

Mots-clés: éducation à l'IA, littératie en IA, IA générative, conception pédagogique, formation des enseignants

Introduction

The field of education has been disrupted by powerful artificial intelligence (AI) technologies with user-friendly interfaces that can see, hear, speak, and help in real time, allowing for more natural human-computer interaction (Bauschard, 2024). Today's AI learning companions are being developed with emotional quotient, intelligence quotient, and adaptability or adversity quotient. The research goal of companies training AI systems is artificial general intelligence, meaning a machine can do any task better than a human and "can self-teach and solve problems it was never trained for" (Amazon Web Services, n.d., para. 4). At a time of rapid and radical technological change in our world, education is more important than ever. Teachers need to be equipped with AI literacy skills and knowledge to foster learning environments where generative artificial intelligence (GAI) is used to enhance learning outcomes, promote equity, personalize learning, and prepare students to live and work in a world of advanced AI.

This article introduces the Student AI Literacy (SAIL) framework, which we developed through an iterative process of professional reflective inquiry with the goal of supporting teachers to use GAI creatively and responsibly. Members of the teacher education community were invited to critique the

SAIL framework and "begin to use, build on, develop, adapt, adjust, and innovate the work in ways meaningful to their own teaching and learning context" (Loughran, 2005, p. 14). Next, we reflect on how we facilitated a constructivist learning environment in which students were invited to co-author an open-access textbook, *Teaching and Creating With Generative Artificial Intelligence* (ETAD 402, 2023). This assignment aimed to empower preservice and in-service teachers to critically evaluate how GAI can support or harm learning in formal educational settings. We discuss the implications for facilitating AI literacy amongst educators, building on the issues in the literature and analyzing what the COVID-19 pandemic revealed about teachers' technology training and their challenges in using technology effectively. Through collaborative reflective practice (Bullock & Butler, 2022), we apply the insights from our inquiry to contribute five targeted recommendations for integrating AI literacy across teacher education curricula.

Literature Review

Artificial intelligence technologies have transformed how people learn, create, connect, and work in our world (Ciampa et al., 2023; MacDowell & Korchinski, 2023; Zhang & Aslan, 2021). While AI has been traditionally associated with computer science and technical disciplines (Casal-Otero et al., 2023), the extensive reach of GAI throughout society necessitates its integration into teacher education curricula (Bauschard, 2023; Celik et al., 2022; Nazaretsky et al., 2022). Preservice and in-service teachers must develop critical AI literacy skills to serve as role models for responsible use and prepare future student generations to become "effective users, informed questioners, and reflective producers" (Johnson, 2023, p. 172). Long and Magerko (2020) defined AI literacy as "a set of competencies that enables individuals to critically evaluate AI technologies; communicate and collaborate effectively with AI; and use AI as a tool online, at home, and in the workplace" (p. 2). Their definition highlights the essential skills and competencies needed to thrive in a world increasingly influenced by AI.

Future educators will benefit from GAI's assistance in finding diverse instructional solutions for varying learning needs within the classroom. While teachers need not be GAI experts, they must possess appropriate competencies and confidence to integrate technology in ways that are responsible and innovative (Cope et al., 2020; Kaplan-Rakowski et al., 2023; Kim et al., 2022). Using prompting techniques, teachers can generate personalized learning materials to differentiate instruction, including supplementary readings, study guides, flashcards and worksheets, interactive media, illustrative images and artwork, and simulations and games to enrich the learning experience (MacDowell & Korchinski, 2023). However, simply focusing on the basic or practical uses of AI education is insufficient. Teacher education programs must extend training beyond the application of GAI to foster a deep understanding of the technology: how it works, who made it, who profits, and how it will affect daily life and society (Bauschard, 2023; Long & Magerko, 2020; Park, 2023). For example, the ROBOT evaluation tool by Hervieux and Wheatley (2020) is a helpful aid in guiding students to consider AI education in terms of its reliability, objective, bias, ownership, and type (ROBOT).

The AI literacy competencies of teacher training programs should not be assumed, as the ability to use technology does not equate to AI literacy practices (Hagerman et al., 2020; Johnson, 2023; Prachagool et al., 2022). Teachers must engage in critical dialogues and experiential lessons to gain the knowledge required for integrating technologies to enhance learning; however, concerns about their unpreparedness for using GAI are widely acknowledged (Celik et al., 2022; Kaplan-Rakowski et al., 2023). Zhao et al. (2022) drew attention to teachers' lack of AI literacy and called on governments to increase professional development and design training that values educator agency and expertise as "motivation and attitude towards AI is one of the important factors influencing AI literacy" (p. 11). Park (2023) argued that teacher training programs need to provide the "practical experience of integrating acquired artificial intelligence into classes rather than simply learning AI literacy knowledge" so educators can develop confidence and self-efficacy (p. 2). Furthermore, we call attention to Johnson's (2023) argument that "policing is not pedagogy" (p. 172) and agree that strict surveillance or punishment to avoid the dishonest use of chatbots are insufficient measures to foster genuine understanding and responsible use of GAI.

As a disruptive technology, GAI has had a polarizing effect on the educational community, with attitudes ranging from unwarranted confidence and excessive use to outright resistance and suspicion (e.g., Akgun & Greenhow, 2022; Celik et al., 2022; Cope et al., 2020; Kim et al., 2022; Zhang & Aslan, 2021). Dispositions of mistrust and opposition tend to divert attention towards enforcing rules and discipline, overshadowing the more human aspects of education, such as nurturing relationships, curiosity, imagination, and joyful learning (Casal-Otero et al., 2023; MacDowell & Korchinski, 2023). University courses that educate about the benefits of GAI—such as enhanced creativity, increased productivity, and augmented capabilities—play a pivotal role in preparing teachers for future classroom scenarios that will benefit from innovative applications of AI education (Bauschard, 2023; Nazaretsky et al., 2022; Zhou et al., 2022). Teacher education programs should nurture critical mindsets, considering how cultural and ethical dimensions are inseparable from technological development. As Johnson (2023) argued, "Technologies do not exist in isolation from cultural practices but rather reflect and reify the practices and ethics of the designer(s)" (p. 170). By encouraging educators to contribute to the design and evaluation of AI-enhanced instruction, we can empower them to shape their professional identities as leaders in AI literacy, extending their influence within the classroom and beyond (Celik et al., 2022; Park, 2023).

Research Design and Methods

A collaborative self-study method was employed to examine professional practices, drawing inspiration from the methodological work of Bullock and Butler in *Learning Through Collaboration in Self-Study* (2022). The aim was to deepen understanding and articulate our approach to preparing educators to teach and create with GAI. Building on the rationale of Lock et al. (2020), collaborative self-study was selected as a suitable research method to "share and illustrate examples of our professional practice" (p. 7) in a way that is meaningful and applicable to other teacher educators. We offer an illustrative case focused on the instructional design of an online course, Multimedia Design and Production (ETAD 402), making our practice transparent, analyzing the tensions and challenges that emerged, and providing recommendations based on our pedagogical experiences. Acknowledging the limitations of collaborative self-study, including the potential for bias and the subjective nature of self-reporting our practices as teacher educators (Vanassche & Kelchtermans, 2015), we thoughtfully include teacher perspectives of their learning in ETAD 402 to enhance our case's credibility, trustworthiness, and applicability.

Teachers included 27 preservice and 8 in-service teachers enrolled in an elective three-credit multimedia design course over 13 weeks during the fall term of 2023. The teachers had various areas of expertise, including early childhood, primary, and secondary, and resided in British Columbia, Alberta, and Saskatchewan. The course was delivered online through the Canvas platform, offering asynchronous learning complemented by live Zoom sessions for deeper discussions and support. Teachers were invited to reflect on their learning experiences in the course by completing an open-ended survey designed to gather authentic feedback (Appendix). The survey responses (n = 35) were analyzed to understand the teachers' perceptions of what and how they learned about GAI. These findings helped identify areas for enhancement in our course content and teaching methods. Our inquiry was guided by two questions: How do we prepare teachers to use GAI creatively and responsibly? How can a constructivist online learning environment contribute to developing AI literacy among educators?

Student AI Literacy Framework

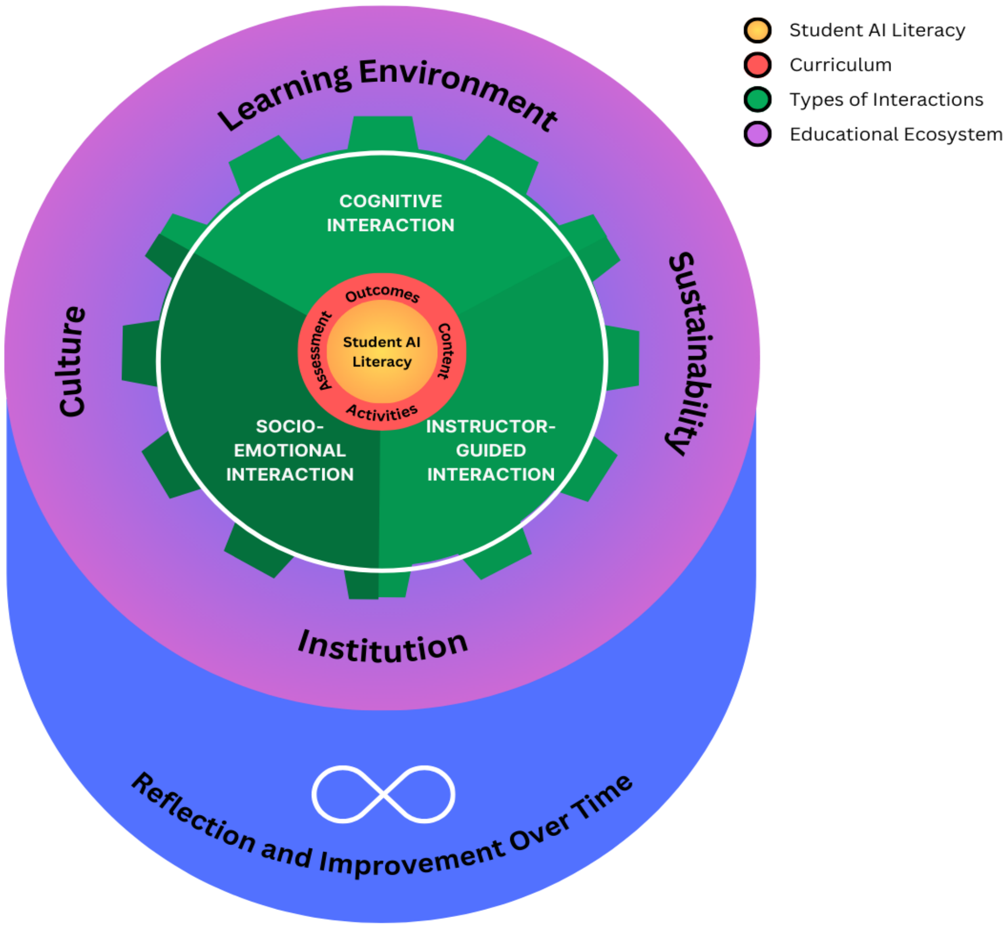
In the development of ETAD 402, the primary focus was on establishing clear and relevant learning outcomes to equip preservice and in-service teachers with the necessary skills and insights to navigate AI education. The following four learning outcomes served as guiding pillars while creating the course curriculum:

- *Demonstrate proficiency in AI literacy:* Develop the ability to critically evaluate how GAI can support or harm learning in formal educational settings.
- *Design inclusive learning environments:* Understand how to design, select, implement, and evaluate educational media to achieve specific learning objectives.
- *Apply instructional design principles:* Acquire the skills and knowledge to create multimedia learning resources for an educational setting that is meaningful to you.
- *Communicate persuasively:* Reflect upon and articulate your philosophy of technology-enhanced instruction, drawing from the course concepts and personal experiences.

During team meetings to plan ETAD 402, it became evident that a framework was needed to guide us in preparing teachers to use GAI creatively and responsibly. After searching the educational literature, we were inspired by the Student-AI Collaboration (SAC) model by Kim et al. (2022), as it resonated with our vision to integrate GAI as a learning partner. Using an iterative design process, we developed the SAIL framework (Figure 1). SAIL embodies a holistic approach to facilitating student AI literacy by integrating it into the curriculum, fostering meaningful interactions, and embedding it within the educational ecosystem. Guided by the SAC model, the SAIL framework was purposefully designed to be intuitive and user-friendly for teachers. Unlike SAC, which emphasizes the curriculum as its core, SAIL centres around student AI literacy. The acronym SAIL serves as an abbreviation for the framework and a metaphor for a voyage of discovery learning with GAI.

Figure 1

Student AI Literacy Framework



Note. Figure developed by the authors.

Types of Interactions in the SAIL Framework

Guided by the SAIL framework, ETAD 402 aimed to scaffold the curricular activities and assessments to align with course learning outcomes and three different types of interactions: cognitive, instructor-guided, and socio-emotional (Figure 2). During the course, preservice and in-service teachers were challenged with a range of cognitive interactions (e.g., ungraded design activities promoting intellectual curiosity and inquiry) and graded assignments requiring deeper independent investigation of the ideas introduced in the design activities. Instructor-guided interactions included providing formative feedback on all assignment drafts before the final version due date, thereby challenging understanding without the pressure of formal assessment. Discussion boards and peer reviews were used to support socio-emotional interactions, providing a social space for authentic conversations and opportunities for professional growth and participation. We received abundant feedback from teachers expressing how much they valued the online socio-emotional interactions: “By speaking with people in the class, the concept of AI became much more humanized and authentic” and “I found all peer interactions to be uplifting, respectful, and useful in continuing my education with technological design." Another teacher articulated the impact of peer interactions:

> *What has struck me first and foremost in reflecting on this course is how important it was to have ongoing communication with my peers to learn authentically. Exploring the different tools and tricks of AI was not only much more in-depth, but simply easier with other people alongside me in the exploration. We all started out not knowing much about how to use AI in the classroom, and we learned through each other and in connection with each other.*

Figure 2

Types of Interactions Aligned with Activities and Assessment

Reflection and Improvement Over Time

Student AI Learning

Interactions	Activities	Assessment
Cognitive Interaction	• Explore course modules and scholarly readings • Test AI applications and analyze the affordances and constraints	• Author AI book chapter • Design AI how-to demo • Midterm reflections • A personal statement acknowledging use of AI
Socio-Emotional Interaction	• Debate with ChatGPT • Design a personalized chatbot • Critical conversations in small group discussions	• Peer reviews of other students' drafts before the final due date • Synthesis of participation and professionalism
Instructor-Guided Interaction	• Leading microlearning activities during team Zoom meetings • Guiding the creation of an open-access textbook	• Formative feedback on assignment drafts • Summative feedback on assignments and design presentations

Note. Figure developed by the authors.

Educational Ecosystem

Within the SAIL educational ecosystem, the primary instructional challenge was facilitating a learning environment that provided a sense of safety, inspiration, and support. We wanted teachers to build confidence in experimenting with GAI without feeling overwhelmed. Hence, we developed low-stakes activities, provided mentorship and formative feedback throughout the course, and offered innovative assignments geared towards developing AI literacy. The constructivist learning environment played an essential role, fostering a culture characterized by values of collaborative and empowered learning through meaningful connections with peers and chatbots. We acknowledge institutional support for the course redesign, including allocating funds for two research assistants. The collaboration pipeline extended beyond ETAD 402, encompassing the co-creation of an open-access textbook, and extending to guidance from colleagues and benefiting from administrative support. A commitment to reflection and continuous improvement over time underscores our instructional design approach, which aligns with GAI's rapid advancement. We recognize that educational ecosystems must evolve and respond to cultural and technological shifts to remain relevant and support students to the best of our capabilities. Capturing the value of adapting to change, one teacher reflected:

> *I initially only took this class as an extra credit, but I now realize how grateful I am to have been given the opportunity to learn from this course. I believe this may be one of the most important, thought-provoking classes I have ever taken. I learned about a changing culture, one built around new forms of technology that will inevitably have an impact on my life and the lives of my students. I learned how to adapt to this new change, ensuring that my students are taught using modern means, but also in a way that is ethical and professional. Above all, I learned the importance of embracing change, allowing students the opportunity to learn with newer resources.*

Preparing Educators to Teach and Create with GAI

The instructional design in ETAD 402 is grounded in constructivist principles whereby knowledge is actively constructed by learners interacting with the course materials, ideas, technologies, and diverse perspectives—and further developed by reflecting on their learning experiences and validating new understandings through dialogue with peers (Ertmer & Newby, 2013). We nurtured an inclusive learning environment where teachers were valued and encouraged to take risks while engaging with the course resources (e.g., readings, videos, and modules equipping them with foundational knowledge) and completing weekly activities and assignments focussed on AI education. As Vaughan and Lee Wah (2020) found in their research on developing preservice teachers' capacity for shared metacognition, our approach goes beyond individualistic learning by incorporating "self- and co-regulation that integrates individual and shared regulation" (p. 1). We aimed to build upon teachers' previous knowledge while fostering new understanding to emerge through collaborative learning experiences. Uniquely, the shared metacognition in ETAD 402 included the teachers' interactions with each other and chatbots.

Like Hollister et al. (2022), we recognize that social interaction with peers and authentic connection with instructors can enhance learning in an online course. Hence, we designed opportunities for social engagement through team design activities and peer reviews, encouraging the teachers to make critical friends and receive feedback to improve their coursework. We also set up asynchronous discussion forums to promote critical dialogue and questioning of AI education concepts drawn from the course readings and videos. To facilitate an effective discussion environment, teachers were grouped into smaller clusters of seven, ensuring a manageable volume of posts to read and write. During live synchronous meetings, teachers were asked to connect theoretical insights with real-world teaching contexts. Questions such as "How does student interaction with GAI impact traditional understanding of learning and assessment?" and "What are instructional design considerations as students interact more naturally with chatbots?" were posed to stimulate reflection and application of the course concepts.

Another key component in ETAD 402 was scaffolding learning through hands-on experiences, offering teachers relevant opportunities to develop a deep and critical understanding of AI education. Each learning activity integrated previous knowledge to facilitate meaningful learning over time and not overwhelm the teachers who began the course without much experience or confidence in using GAI. We started the course by exploring some of the thousands of GAI applications and discussed how teachers who learn to use them effectively have advantages over their peers (e.g., reduced workload and enhanced instructional capabilities). This group exploration led to each teacher choosing one GAI application to research for a book chapter assignment, which involved several drafts and getting feedback from peers, instructors, and chatbots. A concise description of scaffolded learning opportunities in ETAD 402 follows, including weekly practice activities (e.g., designing a personalized chatbot and debating with ChatGPT) and the major course assignment to co-author an open-access textbook.

Weekly Practice Activities

The teachers were invited to design a personalized chatbot, including configuring the initial greeting, setting the level of creativity and predictability in how the chatbot answers, and introducing a unique prompt as the directive. This activity was designed for teachers to gain first-hand experiences with customizing GAI for personalized learning and to develop confidence and proficiency in using new technologies. The approach aligns with Zhao et al. (2022) who found that teachers need AI literacy training that is "diverse rather than conformist, as this may result in teachers' agency not being valued" (p. 11). Following the creation phase, they had an opportunity to test each other's chatbots. This resulted in a meaningful class discussion on the ethical considerations, including how easy it can be to manipulate people through convincing chatbots that are programmed to provide false or misleading information.

One notable course update was transforming a traditional weekly discussion forum into a debate with ChatGPT. This activity was designed to discern how teachers demonstrate empathy and relate to an AI chatbot. Additionally, the teachers learned how to cite their ChatGPT debate using the correct APA format, reinforcing scholarly practices in AI-assisted conversations (Sullivan et al., 2023). First, a detailed prompt was provided for the teachers to input into ChatGPT, which trained it to offer counter arguments and thought-provoking questions in response to the teachers' arguments. Next, the collaborative aspect of this activity invited the teachers to post links to their debates in the Canvas discussion forum. The teachers were not required to use ChatGPT; they had the option of learning by reading and commenting on their peers' debates, thereby fostering a dynamic exchange of reflections and critical perspectives. As Kaplan-Rakowski et al. (2023) discussed, providing inclusive options for the weekly assignments is necessary as some teachers may have privacy concerns or other issues with AI chatbots.

The effectiveness of the weekly practice activities in ETAD 402 is evident by its transformative impact, offering teachers forward-thinking opportunities to develop practical skills using GAI multimedia design. Feedback collected was positive, with teachers expressing gratitude statements such as: "Feeling more comfortable with AI has been worth its weight in gold to me" and "This course taught me a lot about generative AI tools, the ethics surrounding them, and the importance of thinking critically about the tools we use." Many teachers commented on the relevance of the course content and how it challenged them: "Due to the format and required components of this course, I have grown as a teacher .... Although at times stressful, this has been the most rewarding course I have taken in this program." Another common theme reflected was their initial fear and uncertainty at the beginning of the course, as illustrated in this example:

> *I had been nervous about coming into this course and in complete honesty, still felt nervous in the thick of it; there are so many opinions about AI in general, but AI in the classroom is a complex concept even more so. However, this course helped me feel comfortable with the changes to come and to deconstruct many of my previous beliefs about technology in the classroom; I now look forward to teaching with AI!*

Major Course Assignment: Co-Authoring an Open-Access Textbook

To make an academic writing assignment more meaningful and impactful, each teacher was challenged to contribute a short book chapter to an open-access textbook titled *Teaching and Creating With Generative AI* (ETAD 402, 2023). Amongst the 35 chapters, the teachers explored a diverse selection of low- or no-cost GAI applications designed to enhance teaching and learning, including NoleJ (microlearning), Breathing AI (wellbeing), AIVA (music education), Gliglish (language learning), Eduaide AI (differentiated instruction), Lumen5 (video creator), and Gamma (presentation creator). A feature of the textbook is that every chapter offers step-by-step instructions, accompanied by screenshots and video demonstrations, showing readers how to benefit from the featured AI. Another feature is that the chapters offer insights on critical AI literacy with considerations for integration in curriculum and instruction. Uniquely, the chapters begin with a visual introduction through a GAI image, including the application and prompt used. For example, Figure 3 is the image representing chapter 32, generated using the AI tool Imagine Art with the prompt: "wilderness of knowledge, compacted in understanding" (ETAD 402, 2023).

Figure 3

Image Representing Chapter 32 Titled "Expanding your NoleJ" (ETAD 402, 2023)

To facilitate the writing process, a template was provided to guide the teachers in authoring well-balanced chapters that analyzed the affordances, constraints, and tensions associated with AI education (Table 1). We assigned the textbook a Creative Commons Attribution Non-Commercial Share Alike 4.0 International Licence (CC-BY-NC-SA-4.0); however, GAI images are uncopyrightable. Building on Sullivan et al.'s (2023) research into ChatGPT, academic integrity, and student learning, we asked each teacher to be transparent in documenting the role of GAI in their assignments. For example, one author acknowledged:

> *ChatGPT was used in writing this chapter for the purposes of generating image prompts, as well as assisting with some editing and paragraph structure. Paragraphs were written, re-written, and summarized by the author in his own words. All independent research and citations were conducted by the author. Craiyon AI was used for image generation, as indicated throughout the chapter and presentation. Craiyon AI images were used in combination with Photoshop and image references from Google and Bing for educational purposes. WOMBO Dream AI image generator was used for cover art generation.*

Table 1

Guiding Template for the Book Chapters (Abbreviated)

Chapter part	Guidance
Chapter title	The title is the shortest one-sentence description of your chapter. Make it interesting, unique, descriptive, and concise.
GAI image	Create an image representing your chapter (include the prompt and application).
Introduction	Provide an overview of the chapter's purpose and relevance.
Critical AI literacy	Explain how the GAI tool connects to the curriculum and training context, emphasizing the need for critical AI literacy.
Affordances and constraints	Analyze the GAI's educational potential and provide any limitations or restrictions readers should know.
How-to instructions	Provide instructions or guidance for using the GAI tool.
Prompting	Provide insights on how to generate better results with effective prompting techniques.
Recommendations	Offer recommendations, readings, online communities, or additional resources to enhance the reader's understanding.
Video demonstration	Create a how-to guide demonstrating GAI performing the task.
References	List all references, including the GAI applications and chatbots.
Acknowledgement of GAI use	Include a personal statement describing how you used GAI to enhance your chapter.

Teaching and Creating With Generative AI (ETAD 402, 2023) extends its impact beyond our class. The teachers appreciated the pedagogical value of the co-authored textbook and repeatedly mentioned they felt an immense sense of pride contributing to what they see as a ground-breaking resource for assisting other educators to integrate GAI in their practice. When asked to provide one word describing their chapter, the most frequently mentioned descriptors were "accomplished," "useful," "proud," "satisfied," and "informative" (Figure 4). Several teachers remarked on their augmented capabilities: "I learned how AI can help me create more inclusive lessons and open up many opportunities for differentiated instruction" and "The biggest thing I have come away with is the significance of modelling positive AI use for my students." Initially approaching the course with minimal expectation for a genuine learning experience, another teacher expressed a transformative shift in perception:

> *At the beginning of this course, I only wanted to get the course credits and get out. I had no intentions of getting a real learning experience. I soon found out that I was wrong. I did not think that I would get to explore things like incorporating AI into teaching lessons. I thought that AI*

was only something that people used to cheat on assignments, and I never considered that there were ways to positively use these programs.

While the teachers had positive experiences and were grateful for being challenged to learn about GAI, constructive criticism on minor instruction design issues was expressed. Notably, suggestions included allowing more time for mastering their selected GAI application before writing their chapter, providing a weekly checklist of tasks with well-defined directions and due dates, and improving consistency and flow within the open-access textbook for a better reading experience. Pressbooks (https://pressbooks.com/) was chosen as it is currently the most user-friendly online software for publishing open educational resources in multiple formats accessible on mobile devices, desktop browsers, and e-readers. However, some educators encountered difficulties formatting their chapter in Pressbooks and highlighted the importance of peer support in overcoming these technical hurdles. Despite enjoying the autonomy and creative freedom in the learning process, a few educators felt overwhelmed by the vast array of GAI tools, suggesting: "The template was helpful for this, but perhaps making the scope of topics available a bit less broad would give students more direction when beginning the project."

Figure 4

Wordcloud Showing Most Common Teachers' Responses to the Question: "Give One Word to Describe Your GAI Book Chapter"

Note. Figure developed by the authors.

The teachers unanimously responded that co-authoring a textbook was a useful assignment in an online university class, noting that it allowed them to learn independently and collaborate with peers. Their reasons for recommending this assignment for future classes include: “Designing a textbook together allows for increased collaboration and interaction amongst peers in an online setting and gives everyone in-depth information on a variety of tools that otherwise they would not have been able to explore on their own.” Additionally, “It contains everything that an instructional activity should have. It was fun, it allowed for individual expression, there was a real-world aspect to it, and it involved problem-solving, and higher order thinking skills.” Many teachers appreciated the relevant opportunity to explore, apply, and share their knowledge: “The textbook format leads students to consider how their chapter might be useful to someone that reads the textbook rather than just creating something to hand in for a grade,” and “My mom is a teacher and I plan on sharing the textbook with her because not only can she see some of the work I’ve done in university, but also share in the learning from all my classmates.”

Artificial intelligence literacy growth and development was a recurring theme in the teachers’ reflections. For example, “I increased my own AI literacy, as well as learned how to incorporate this literacy into multimedia educational resources and implement AI into the classroom to further support learning” and “I know AI will always be changing and growing, but I will be changing and growing with it. And I hope that wherever it may go, it will allow me to be the best teacher I can be.” The assignments and reflective discussions allowed for deep and meaningful learning about the ethical dimensions of GAI, voicing concerns, and contemplating proactive measures for teaching and learning. After reflecting on the course outcomes, however, we recognized the need for additional coursework to increase opportunities for teachers to develop their AI literacy skills. Consequently, we are designing a new module including deep fakes, misinformation, and social manipulation (Akgun & Greenhow, 2022; Celik et al., 2022). Our initiative underscores how the ongoing evolution of the course content needs to align with the fast pace of technological advancements in order to provide relevant guidance on the evolving ethical complexities. Responsible use of GAI was articulated by a teacher who reflected on the value of educators as positive role models:

> *By using AI openly, educators set an example for their students on how to foster a constructive relationship with AI. By allowing students to engage with AI in ethical ways that promote active learning, creativity, and critical thinking, educators are encouraging students to continue engaging with it positively.*

Discussion and Implications

Preparing Educators to Teach AI Literacy

Research from the COVID-19 pandemic highlighted a significant issue: teachers were largely unprepared for the sudden shift to remote teaching facilitated by digital technologies. Lacking sufficient knowledge and resources, teachers struggled with adapting to new platforms for delivering a modified curriculum to students in a home environment (Francom et al., 2021). The focus on the emergency use of technologies, coupled with limited guidance from school administration and the realization that some students were more technologically adept, significantly heightened teachers’ stress and anxiety levels

(Prachagool et al., 2022; Robinson et al., 2022). Teachers often found themselves reacting to challenges beyond their control, such as student cheating and disengagement (Hollister et al., 2022). Their unpreparedness highlighted a gap in the technology training provided by teacher education programs across Canada.

Further concerning, the pandemic emphasized the long-standing deficit of digital literacy education within Canadian school curricula, as noted by Hoechsmann and Poyntz (2017). Teachers, parents, and students were unprepared for the increased screen time (e.g., they lacked understanding of how to engage with technology in healthy ways and knowing when to disconnect). Many students engaged in media multitasking, simultaneously using multiple devices or windows for activities such as watching TikTok or YouTube videos and texting friends on Snapchat while completing homework assignments or participating in Zoom classes (Hollister et al., 2022). Students spent extensive time in front of screens, often unsupervised, without the ability to evaluate the quality of the content they viewed and consumed. MediaSmarts (2023) reported deficiencies in digital literacy skills amongst Canadian youth and argued for a "national strategy to prioritize digital media literacy education in classrooms and communities" (p. 5). These findings provoke a critical question: Knowing the gaps in students' digital literacy skills (both prior to and during the pandemic), have teacher education programs adapted to prepare educators with the necessary skills to teach critical digital literacy? Or has the urgency to address this issue diminished with the pandemic's decline?

The advent of the post-pandemic era introduced another major technological disruptor in the field of education: GAI, which presents new tensions, affordances, and literacy concerns (Akgun & Greenhow, 2022; Bauschard, 2023; Johnson, 2023). Generative AI offers educators the potential to personalize learning experiences and foster inclusivity by bridging disparities between students of varying cultures and backgrounds (Cope et al., 2020; Zhang & Aslan, 2021). However, without appropriate oversight, GAI could exacerbate issues such as the digital divide, misinformation, privacy violations, and reduced critical thinking due to overreliance on technology (Casal-Otero et al., 2023; Pedró et al., 2019). The effectiveness of any educational technology, GAI included, depends on how it is developed and implemented in classroom learning environments. Therefore, it is vital to equip teachers with "the new literacies of 21st century technologies," empowering them with AI literacy training to guide the responsible and innovative use of AI and prepare students for "the literacy futures they deserve" (Ciampa et al., 2023, p. 190).

Recommendations for Teacher Education Programs in Canada

We encourage teachers to adopt a dual role as innovators, exploring GAI's possibilities for enhancing educational experiences, and guardians, understanding and mitigating GAI's potential risks. Considering the challenges teachers faced during the pandemic, particularly their unpreparedness to adapt to digital technologies, we see an urgent and substantial need for teachers to have continuing professional development and training in AI literacy. To this end, we recommend five strategies to facilitate the meaningful integration of AI literacy in teacher education programs.

Do No Harm With GAI

Promoting responsible use must be a top priority. Teachers need to understand the ethical dimensions associated with AI education. To the overworked educator, GAI's ability to instantly generate content is enticing: written work, lesson plans, assignment feedback, and information gathering take mere minutes instead of hours or days (MacDowell & Korchinski, 2023). Generative AI content, however, can be biased, misleading, and harmful if not carefully analyzed by a human (Park, 2023). Where it is increasingly difficult to distinguish real from manipulated media (e.g., images, text, and video), teachers must learn about GAI misuses and deep fakes that can serve to disseminate misinformation and disinformation (Bauschard, 2023). Teachers must develop critical thinking skills (e.g., evaluating information from chatbots, discerning authenticity, and identifying bias within algorithms) to guide students toward responsible use (Casal-Otero et al., 2023).

Develop Chatbot Communication Skills

Teachers need training on how to communicate and collaborate with AI chatbots (Sullivan et al., 2023). Our research indicates that teachers' confidence and trust in AI education increased after they developed prompting skills and learned how to fine-tune their interactions to maximize the potential of chatbots as helpful teaching aids. Chatbots must be provided with information such as the context, role, tone, detailed instructions, and examples (or non-examples) of the expected output. Without well-crafted prompts, there is a risk of chatbots generating irrelevant or subpar content, leading to skepticism and reluctance among teachers to integrate GAI into their practice. Developing effective communication skills will help teachers mitigate misconceptions and foster understanding that collaborating with chatbots requires a careful balance of fearful respect and responsibility (Celik et al., 2020; Ciampa et al., 2023).

Facilitate Experiential Learning With GAI

Educating teachers about the importance of AI literacy is essential; however, theoretical knowledge without practice is insufficient. Teachers need hands-on opportunities to experiment with various GAI applications and evaluate their applicability for diverse educational settings (Nazaretsky et al., 2022; Zhao et al., 2022). To foster AI literacy, teachers must comprehend and demonstrate responsible and transparent use of GAI (Ciampa et al., 2023). Our research suggests that teachers benefit from assignments that focus their time and attention on experiential learning with GAI while developing theoretical understanding by discussing course readings. Further, it is beneficial to incorporate low-stakes practice activities (e.g., designing a chatbot personality, debating with a chatbot, and generating videos from text). These practice-oriented tasks familiarize teachers with various approaches for integrating GAI in curriculum, instruction, and assessment (MacDowell & Korchinski, 2023).

Infuse AI Literacy Across the Curriculum

Preservice teachers should graduate with the confidence and knowledge of how to leverage GAI to benefit their practice (Park, 2023). In-service teachers who are well-versed in the affordances and constraints of AI education will have the necessary skills to prepare their students to participate in a society where AI is ubiquitous (Kaplan-Rakowski et al., 2023). Our study is limited as it focuses on a singular, stand-alone course aimed at educating teachers about GAI design, concepts, applications, and ethical considerations. A more effective approach would be integrating AI literacy across all teacher education courses involving pedagogical and content knowledge (Nazaretsky et al., 2022). A shared commitment from researchers, administrators, and key stakeholders in the educational sector will contribute to developing professionals with AI literacy skills and "build a stronger and more flexible foundation for digital literacies teaching and policies in Canadian systems of schooling" (Hagerman et al., 2020, p. 26).

Address Inequalities in AI Education

The United Nations' fourth Sustainable Development Goal aims to provide and promote inclusive, equitable, and quality education for all, a commitment that extends to powerful learning technologies such as GAI and chatbots (Pedró et al., 2019). Teachers need to understand how the digital divide increases when marginalized communities do not have Internet connectivity, device availability, or equal learning opportunities. This knowledge can help them implement strategies ensuring that all students, irrespective of their socioeconomic or cultural backgrounds, have equitable access to the benefits of AI education (Bauschard, 2023). In our research, teachers collaborated to produce an open-access textbook via Pressbooks, which provided a platform to share their collective experiences, best practices, and design expertise. The co-authored textbook highlights the value of co-creating open educational resources in a university course. By fostering a culture where knowledge and experiences are openly shared, we can work toward bridging the AI literacy gap amongst educators and ensure the benefits of AI education are more evenly distributed (Celik et al., 2022).

Conclusion

In response to the need for practical and actionable frameworks to guide the use of GAI in K-12 and higher education classrooms, our research team designed the SAIL framework. SAIL contributes a holistic approach to integrating AI education, including the dynamic interplay of curriculum, culture, learning environments, sustainability, and institutional support. Teacher-guided interactions in SAIL highlight the importance of human mentorship in preparing students to use GAI creatively and responsibly. We invite researchers, instructional designers, and practitioners to build upon, refine, and evaluate the SAIL framework; the aim is to share the benefits of AI education equally and be proactive to prevent unforeseen harm.

Our open-access textbook, *Teaching and Creating With Generative AI* (ETAD 402, 2023), offers tangible examples of how GAI can foster learning experiences that are experiential, interactive, and adaptive. Through collaborative exploration, the teachers learned how GAI can augment their creativity, productivity, and instructional design skills. The textbook demonstrates how traditional concepts of learning and creativity are evolving as human collaboration with GAI is becoming normalized. Additionally, the textbook brings forth numerous challenges educators face, such as the ease of creating deep fakes, preserving academic integrity, data privacy, copyright concerns, harmful biases, and overreliance on technology in an AI society.

We call on teacher education programs across Canada to provide continuing professional development in AI literacy for educators at all stages, from faculty members to preservice and in-service teachers. Artificial intelligence literacy in Canadian schools and education systems will grow as we share visions and strategies that promote inclusive and equitable practices, drawing from our collaborative self-study and the related literature reviewed as part of this research. We acknowledge there is no easy or safe road ahead. Integrating GAI into classrooms is risky, and so is leaving it out of classrooms. Faculties and colleges of education across Canada must work together, planning carefully to navigate the tensions, to cultivate a culture of AI literacy in our schools and beyond. Given GAI's profound impact as a disruptive technology, nationally and globally, the need for leadership is urgent.

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Appendix

1. Give one word to describe your GAI book chapter.
2. What is the greatest thing about your book chapter (something that you are proud of or that you accomplished)?
3. What was the hardest or most frustrating part of researching, writing, or designing your book chapter?
4. How can the process of co-authoring an open textbook be improved?
5. Did you learn any new technical skills or GAI skills? If yes, please elaborate.
6. How did the collaborative peer learning environment in the course influence or support your learning?
7. How do you envision using GAI in your work as a teacher or as a student in your future academic pursuits?
8. How confident are you in your ability to discern the ethical considerations and potential biases associated with using GAI and chatbots?
9. Which features of GAI do you find the most valuable for teaching and learning?
10. Overall, how do you feel about the potential impact of GAI on education and the creation of instructional materials?

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