Understanding Grade 4-8 Teachers' Instructional Practices and Beliefs as a Function of Transdisciplinary Coaching in STEM-Language Literacy

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Abstract

Changes in STEM education in Ontario have resulted in the need for teachers to have professional development and coaching support to introduce a cross-curricular, transdisciplinary instructional approach while honouring teachers' knowledge, attitudes, and instructional methods. This study sought to introduce Grade 4–8 teachers to transdisciplinary STEM and language literacy through a five-session coaching partnership with the Principal Student Investigator. Participating teachers and students solved real-world problems using a transdisciplinary rather than typical single-subject instructional delivery. The study adopted a generic descriptive qualitative approach (Elliot & Timulak, 2021) to investigate Grade 4–8 teachers' practices and beliefs. Four types of data—pre-questionnaires, interviews, researcher reflections, and fieldnotes—were coded to highlight recurring concepts and descriptive words and expressions. Three meaningful themes and sub-themes were identified to respond to the research question. Findings indicated that changes to teacher instructional practices were possible from starting with structured practices, shifting to inquiry-based, student-driven learning, seeing increasing student motivation and problem-solving and identifying the need for more coaching time. Teachers also saw the benefits of learning coding alongside students and how to implement cross-curricular assessment. Teacher beliefs varied with regards to conceptions of teaching language literacy in STEM; their initial apprehensions shifted to realizations, reservations about accountability related to transdisciplinary learning were expressed, and the positive outcomes of transdisciplinary learning impact on students was witnessed. A productive working relationship was established between the coach and teachers. The teachers expressed that the coach was flexible and open, met the teachers where they were at, listened to their needs, and adhered to the gradual release of responsibility to extend the teachers to their next level of instructional acumen. The study identified how teachers' practices and beliefs might change when provided with coaching support through professional learning (PL) sessions focused on transdisciplinary approaches to STEM-Language Literacy education. Implications for practice include coaching support for teachers to evolve from single-subject teaching to adopting STEM-Language Literacy with the transdisciplinary approach. Implications for theory suggest that scaffolding teachers through the PL experience with STEM-Language Literacy is consistent with the experiential learning theory (Dewey, 1938).

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CHAPTER ONE: INTRODUCTION

As an educator, I contend that education and the way teachers practice must evolve. However, one can observe, when walking into some elementary school classrooms, in the Niagara region, that many teachers' practices and beliefs about how students learn have not changed over the past decades. There are desks, chairs, hands raised, students sitting in straight rows or small groups, and invariably somewhere in the classroom there will be a daily schedule posted with titles of curricular subjects and designated recess/lunchtime. These curricular subjects are for the most part still being taught in isolation or silos. In my role as a Science, Technology, Engineering, and Mathematics (STEM) coach, with a small school board in Southern Ontario, I have interpreted two issues that teachers experience: (a) that, unless they have a strong background in science, mathematics and technology, they are concerned about their competency and how to teach the curriculum in these areas; and (b) there is perceived pressure to get through the curriculum to get student grades for reporting. It is not uncommon to hear statements like, "I have to pick up the pace," or "I am already behind, I'm not going to get through everything."

Along with asking for content help, or expressing there is too much in the curriculum, I occasionally see a teacher using a rich or culminating task in a cross-curricular unit of study, but this is the exception. Over the years, I have worked with teachers who fear they will not cover all the curriculum if they do not go page-by-page, note-by-note, and test students' knowledge using quizzes or exit cards. In the past few years, within my school district, there has been a slight movement to teach using more interdisciplinary methods where teachers include more than one curricular subject, but I often wonder what instruction would be like if teachers were selecting a compelling theme or contemporary issue and then facilitating learning in a transdisciplinary approach? Briefly, the transdisciplinary teaching approach promotes the incorporation of knowledge from other disciplines into the diversity of real-world problems and applications (Back et al., 2016). There are some very progressive classrooms that I have observed in my role as a STEM coach; however, the reality is that these practices are rare and certainly not the classroom experience for all elementary students.

There are two major domains involved in teaching: (a) teachers' actions or practices, and (b) teachers' beliefs and knowledge (Mansour, 2009). Historically, research has demonstrated that teachers will initially teach the way they were taught (Britzman, 1991). Mazur (2009), in talking about his own physics teaching experience at Harvard, saw that most teachers simply replicate the teaching strategies of their mentors. There has been research and a call for teacher practices to change; however, particularly in the areas of STEM education, the adoption of inquiry-based teaching methods has been slow (Bell, 2016; Kelly et al., 2017). Approaches that are inquiry-based, problem-based, land-based, and place-based all suggest engaging instructional practices (Bell, 2016; Kelly et al., 2017) and yet, it is my experience that the elementary teachers that I work with, still schedule their day by individual subject disciplines. Unfortunately, school scheduling does restrict fulsome implementation of STEM activities in elementary schools (Shernoff et al., 2017), however, by considering teaching cross-curricular within scheduled subject times teachers and students would benefit.

Teachers' beliefs can be framed as "the heart of teaching" (Vartuli, 2005, p. 78). Self-efficacy, which is rooted in Bandura's (1977, 1986) social cognitive theory, teachers' judgment of their own ability to engage students and facilitate their learning. With respect to STEM education, teachers' confidence in their ability to teach the STEM subjects is essential to being an effective teacher (Kelly et al., 2017; Wenner, 1995). Teachers can gain knowledge through theory, lessons, and preservice and in-service education programs; however, teachers' beliefs are more likely composed of their thoughts regarding education, child development, teaching, and learning, which can be affected by teachers' personal and professional experiences (Pajares, 1992).

The study of teachers' beliefs raises important questions such as how teachers make decisions in the classroom on a daily basis; what teachers refer to or rely on when planning, making decisions, or interacting with students; and how teachers develop their personal beliefs about a variety of issues with respect to specific areas and the specific beliefs that operate in specific situations (Kim & Han, 2015). There are a number of researchers who agree that teachers' beliefs can affect, inform, and guide their teaching practices (Kim & Han, 2015; Mansour, 2009; Pajares,1992). Researchers do agree that attention should be focused on how beliefs about teaching are acquired, maintained, and altered (Bell, 2016; Cassidy & Lawrence, 2000; Hashim, 2020; Lin et al., 2001). Moreover, teachers' beliefs about their own teaching capabilities do influence how effective their teaching practices are (Tschannen-Moran & Hoy, 2001).

Context of the Research

The year 2020 was a unique time globally, and prior to the release of the *Grade 1-8 Mathematics Curriculum* (Ontario Ministry of Education, 2020) teachers and students were learning online from home as the pandemic introduced COVID protocols that shut schools. To keep control over the further spread of the pandemic, countries installed measures that restricted physical proximity which ultimately resulted in the closure of schools (OECD, 2020; World Bank, 2020). In September 2020, many students were still learning online. This reality presented its own challenges that are not part of this study.

Curriculum

In the last three years (2020-2023), teachers in the elementary school system in Ontario have experienced a number of changes to the curriculum in the STEM disciplines. In September 2020, the Ontario Ministry of Education introduced the new *Grade 1-8 Mathematics Curriculum*. With this curriculum came the requirement of teachers to teach coding and computational thinking; teachers in Ontario needed to learn how teach coding to their diverse learners and how to recognize coding in everyday situations. Teachers expressed a feeling of being overwhelmed with the curriculum and its expectations and Ontario teachers expressed concerns about not receiving formal training in the new curriculum (Thompson, 2020).

Since 2020, professional development (PD) and professional learning (PL) opportunities have been offered after school and during the summer through school boards' PD offerings. Yet not all teachers are available to take PD and PL during after-school hours due to family and life responsibilities; moreover, teachers' unions state that any form of PD outside the instructional day is voluntary (ETFO, 2008). Teachers continued to express apprehension and wonder how they could implement coding and computational thinking into their class curriculum; teachers questioned why PD was not provided before the curriculum was released (Thompson, 2020). Liz Stuart, the then Head of the Ontario English Catholic Teachers' Association (OECTA), expressed that teachers required proper "time, resources and supports" (Thompson, 2020, para. 12) and that "Ontario teachers say it's 'unrealistic' to unveil new math curriculum now" (Thompson, 2020, para. 12). Mary Reid, a math curriculum specialist with the Ontario Institute for Studies in Education at the University of Toronto agreed and added that "research shows that if you just put it out there and give it to teachers, without real professional development support, it's not going to be implemented successfully" (Thompson, 2020, para. 18). Professional learning is necessary to support change in teachers' practices that prepare teachers to achieve improved student outcomes (Aboagye et al., 2020; Darling-Hammond et al., 2017; Flores, 2011). Teacher practices would need to change to adapt to this new requirement and teacher beliefs in their ability to teach coding would then influence the effectiveness of how much coding they would teach.

In late Spring 2022, the Ontario Ministry of Education announced its new *Grade 1 to 8 Science and Technology Curriculum*. The curriculum was released, and teachers began implementing it as of September 2022. Included in the new Science curriculum is an emphasis on STEM with a focus on coding expectations, highlighted with its own strand or category: “Strand A: STEM” (Ontario Ministry of Education, 2022). The Ontario Minister of Education, Stephen Lecce, in his address regarding education and the new *Grade 1-8 Science and Technology curriculum* emphasized that this new Science curriculum, “focus is on modernizing education” by teaching coding from Grade 1 (Lecce, 2022, para. 2). Teachers, who were apprehensive regarding the math coding introduction, were now expressing feelings of being overwhelmed and underprepared for coding expectations in both science and math. According to Karen Brown, president of ETFO (Elementary Teachers’ Federation of Ontario), teachers have had insufficient training or preparation for the new STEM component of the curriculum (CBC News, 2022).

The *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022) also encourages a focus on STEM and emphasizes teaching students’ concepts that are relevant and reflect real-world experiences in a cross-curricular or integrated way. This has created an expression of concern among teachers as they look for support to navigate through all these new expectations for themselves to ultimately teach their students. During an interview for the CBC News (2022) article “Ontario Unveils New Science Curriculum for Students Grade 1 to 8,” Karen Brown spoke of appreciating the curriculum but criticized the “compressed timeline” (para. 17) given to school boards to instruct their teachers in this new curriculum. This statement could dictate a higher demand for coach-teacher collaboration, especially during the school day, for teacher professional learning and how that will look with regards to STEM.

A recent Ontario-based article in *The London Press* titled “As Ontario Rejigs Science Curriculum, Critics Ask: Who Will Teach the Teachers?” (Rivers, 2022) addresses direct concerns from researchers and teachers regarding the new *Grade 1-8 Science and Technology curriculum* (Ontario Ministry of Education, 2022). Western University’s Isha DeCoito, who led a team involved in this science curriculum development expresses in the article that to build teacher capacity, teachers are going to require significant professional development (Rivers, 2022). DeCoito also refers to coding in the curriculum which many teachers have never learned themselves, and states that when it comes to introducing a new curriculum, teachers may or may not embrace the change, and it can take years to see implementation in the classroom (Rivers, 2022).

There is documented precedence for the impact of math and science curricular changes. For example, when the elementary school curriculum was changed in Portugal in 2011, there was an impact on the teachers' sense of professionalism (Flores, 2011). Teachers expressed concern with the lack of support and guidance they were provided to accompany the curriculum changes (Flores, 2011). Similar teacher feelings were witnessed in a more recent study (Aboagye et al., 2020) involving the deployment of a new curriculum in Ghana. Teachers were optimistic about the new curriculum and acknowledged its strengths, yet teachers also held the view that the government should, among other items, train teachers in advance of its release (Aboagye et al., 2020).

In August 2023, the Ontario Ministry of Education released its updated *Grade 1-8 Language Curriculum*. The curriculum context page specifically states, "The Ontario Language curriculum recognizes the value of embedding literacy learning throughout the day" (Ontario Ministry of Education, 2023, p. 62). As well, in *Strand A. Literacy Connections and Applications*, there is a set of specific expectations under the heading, "A3.1 Cross-Curricular and Integrated Learning" (Ontario Ministry of Education, 2023, p. 91). This is the opportunity for teachers to continue to strengthen their literacy practices by engaging in literacy outside of the language period in the classroom such as to integrate other curricular areas.

Based on my experience, in the province of Ontario, many current teacher concerns are related to the new curricula expectations, a sense of not being prepared to teach, not receiving training and professional learning, concern about how to cover all the curriculum expectations, and getting grades for report cards. Teachers in Ontario, as stated in various subject Ministry documents, have time allocations per subject: daily schedules should reflect teaching 120 minutes (Primary) and 100 minutes (Junior/Intermediate) for literacy; mathematics is 60 minutes daily, while science is 150 minutes per week. With these kinds of discrete, time bound stipulations, teachers tend to continue to teach core subjects independently of each other and consequently, "silo" teaching has dominated education as it is easier to schedule and map out (Jacobs, 2022). In Australia, education has frequently been criticized for teaching in 'silos,' where subjects are taught independently of one another (Jacobs, 2022). This may lead to little time for flexible topic exploration and diving deeper into students' expressed interests; consequently, students may only learn content relevant to a single, isolated topic.

As more teachers are beginning to realize the importance of problem solving and student-directed learning, and as the new curriculum is written to address real-world application expectations, teachers need PL support through coaching. Teachers should be coached in how to look at subjects with a transdisciplinary lens rather than single strand or individual discipline delivery (Caton, 2021). The *Grade 1-8 Mathematics* coding curriculum (Ontario Ministry of Education, 2020), the *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022), and the *Grade 1-8 Language Curriculum* (Ontario Ministry of Education, 2023) all provide cross-curricular links and encourage holistic lesson planning and engagement for students. Coaching teachers in how to incorporate cross-curricular and transdisciplinary approaches into their long-range plans would alleviate the stress and pressure teachers feel as they try to cram in all the curricular subjects separately throughout the learning day. This sentiment was expressed by a science teacher, Paris Vasiliou, in the Ottawa-Carlton District School Board (OCDSB) in a CBC News article, "Teachers Fear Impact of 'Crammed' Curriculum on Students" (Chevalier, 2020). Vasiliou stated, "As teachers, we're cramming and trying to get through the curriculum, and for students, it must feel like they're just being bombarded by information" (para. 12). This quote relates to the impact of online learning during the pandemic which is echoed by many teachers who are now back to in-person learning, as they feel even more pressure to help students make up academic skills lost during the pandemic.

Policy

In addition to learning about new content and methods and adopting teaching approaches that address the curriculum, there are many other expectations of teachers. One of these expectations is the teacher's integration of technology in the classroom. At the moment, most teachers view technology as a tool rather than an embedded part of their students' learning process (DeCoito & Richardson, 2018). For technology to be successfully implemented in the classroom, teachers must be knowledgeable about both the technology itself and how to implement it to meet the educational goals (DeCoito & Richardson, 2018). This challenge is paramount in the province of Ontario as the *Grade 1-8 Mathematics Curriculum* (Ontario Ministry of Education, 2020) and the *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022) include coding and computational learning which require teachers to have knowledge of these concepts and the technology to teach them.

Teachers in Ontario also have the expectation of following the *Growing Success* (Ontario Ministry of Education, 2010) document for assessment and reporting. Where assessment plays a key role in education across Canada, in Ontario there is a call for assessment on fair and equitable education for all students (Jang & Sinclair, 2017). Engaging students in inquiry-based learning, aligning to the ways in which students engage with learning in the digital world has shown enhanced efficiency through technological advances (Jang & Sinclair, 2017) and inclusion in the classroom. This is especially true since we are in the post-pandemic era, where teachers and students have had the experience of teaching and learning virtually.

Research has shown that, during the COVID-19 pandemic, student learning was impacted in many ways such as disengagement, attendance problems, and declines in academic achievement (Whitley et al., 2021), amplifying structural inequities, and providing a growing awareness that the experience of the pandemic should motivate new and alternative approaches to teaching and learning (Lopez, 2022). The pandemic proved to be an opportunity for educators to question inequitable educational policies and practices (Lopez, 2022), and to offer new approaches with curriculum. Post-pandemic era education calls for radical action with regards to culturally responsive relevant pedagogy (CRRP) (Lopez, 2022) which can benefit how curriculum is delivered, assessed and who is involved. Teachers need awareness that if they look for interconnected concepts and themes in their teaching and create cross curricular lessons, they can incorporate all required subjects and time allocations, while allowing students exploration of topics of interest.

In Ontario, with the recent roll-out of both the new *Grade 1-8 Mathematics* (Ontario Ministry of Education, 2020) and *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022), elementary teachers must move between these curricula if they want to integrate learning and coding. Many in-service teachers have not learned coding which carries a completely new language and skill set that requires time to adopt into their practice. As well, many elementary teachers are asking for supportive STEM professional development to help build their knowledge, self-efficacy, and enhance their practices (Gardner et al., 2019), as many have not taken a course in science or mathematics past Grade 10. Numerous research studies have been done with preservice teachers describing the reality and consequence of math anxiety and preservice teachers (Bursal & Paznokas, 2006; Gresham, 2009; Novak & Tassell, 2017). Mathematical efficacy is the extent to which the teacher believes they can affect a student's mathematical abilities when teaching them math (Bosica, 2022). In fact, when it comes to math instruction, mathematics efficacy was shown to be associated with the teacher's past experience as a student and how they learned math (Brown, 2012). Similar findings have suggested that with respect to STEM efficacy, only a small number of teachers feel appropriately prepared or comfortable teaching integrated STEM in their classes (Guzey et al., 2014; Tuttle et al., 2016).

Over a decade ago, it was stated that it is essential for teachers to not only use technology to create and enhance inquiry-based opportunities in their classes, but to support the new U.S. curriculum providing more real-world learning experiences for their students (U.S. Department of Education, 2017). In fact, since the U.S. National Science Foundation began using the acronym STEM in 2001, there has been an international movement to increase student engagement and expertise in science, technology, engineering, and mathematics (Jacobs, 2022). As the curricular focus continues to be numeracy and literacy in Ontario schools (Ontario Ministry of Education, 2023), it is important that any attempt to increase participation in STEM must also improve numeracy and literacy skills. To accomplish this, we need to teach our teachers to think across transdisciplinary lines (Schmitt, 1960, as cited in Gillis et al., 2017) and teach students how to develop collaborative thinking outside of the traditional subject silos.

Teachers need to identify how their practices are impacted by their beliefs when teaching STEM and incorporating literacy. Teachers who are comfortable with STEM content and their pedagogical practices might, with coaching support, transition to a transdisciplinary way of covering curriculum (Back et al., 2016). The challenge is helping teachers navigate away from single subject teaching and to begin to think in terms of engaging learners with real-world problems and concepts that draw on knowledge and skills across the disciplines.

A means to support teachers as they work to understand their beliefs while enhancing their practices is through coaching (Hashim, 2020). A coach might collaborate with the teacher on how to code, how to use technology, and how to implement the STEM learning with literacy and transdisciplinary approaches. Working with an instructional coach can help to enhance and improve learning (Hashim, 2020) while improving teacher practice and benefiting student learning (Kraft et al., 2018). Instructional coaches can provide cognitive support by helping teachers make sense of curriculum and instruction (Marsh et al., 2010). In Ontario, the *Grade 1-8 Mathematics* coding curriculum (Ontario Ministry of Education, 2020), the *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022), and the *Grade 1-8 Language Curriculum* (Ontario Ministry of Education, 2023) may be new, but by demonstrating and collaborating with the teachers, coaches may help teachers recognize that they can draw from their past practices to revise those practices into new applications.

Research specifically looking at how STEM coaches are interacting with Ontario teachers to implement the *Grade 1-8 Mathematics* coding curriculum (Ontario Ministry of Education, 2020), the *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022), and the *Grade 1-8 Language Curriculum* (Ontario Ministry of Education, 2023) using a transdisciplinary approach is lacking. Finding a way to help teachers reach all the curriculum goals in a meaningful and engaging way should include coaching in the cross-curricular transdisciplinary approach. This study considered how participation in a professional development coaching model including transdisciplinary approaches for teaching STEM-L education impacted Grade 4–8 teachers' instructional practices and beliefs.

Rationale

The rationale for this present study is premised on current issues in STEM education that relate to teachers' knowledge and associated beliefs, their instructional practices, and their need for professional learning that emphasizes a cross-curricular transdisciplinary approach to STEM teaching. With respect to teachers' knowledge, Quigley and Herro (2016) discuss that many teachers are eager to increase their STEM foundational knowledge (i.e., understanding of the skills and evidence that make up science, technology, engineering, and math) to practice at a time when they must be prepared to teach with technology and 21st century skills, collaborate, and implement STEM and STEAM (STEM with Arts included) curricula. STEM literacy refers to the integration of STEM disciplines and the tools and knowledge necessary to apply STEM concepts to solve complex problems (Hull et al., 2011). This includes the language from the four STEM disciplines and understanding how to apply it to real-world problems and situations. Honey et al. (2014) argued that the disciplinary processes within the many STEM disciplines are not being made explicitly relevant to students by teaching STEM in a more connected way, particularly by contextualizing it in real-world concerns. This would in turn emphasize the notion of authenticity as STEM professionals in the real-world are less likely to compartmentalize each discipline/subject in their professional practice (Breiner et al., 2012). Bush and Cook (2019) also suggest that STEAM (STEM + the Arts) can be interwoven into time that is already dedicated to mathematics and science.

Many contemporary teachers are interested in integrated STEM approaches being an educational focus, but express that they do not believe they are prepared to implement these approaches (Shernoff et al., 2017). Teachers who have little training in STEM education feel overwhelmed by STEM concepts (Hsu et al., 2011; Trygstad, 2013). In some cases, this could negatively affect teacher self-efficacy, their belief in their own competence that they can teach (Bandura, 1997), and it could affect how much STEM learning teachers offer their students. Teachers who have limited knowledge and STEM experience have low self-efficacy beliefs with regards to this type of teaching and learning (Margot & Kettler, 2019). A teacher that feels less comfortable with STEM will not fully engage with STEM curriculum (Margot & Kettler, 2019). Student learning is impacted when teacher knowledge and understanding is “deficient” (McMullin & Reeve, 2014). It is plausible that many current teachers require support through PD and PL delivered by a STEM coach. Indeed, PD and PL provide an essential role in supporting the teachers’ efficacy which in turn supports student learning (Darling-Hammond et al., 2017).

An additional issue is that teachers who have been facilitating STEM education need to look to cross-curricular, student-directed methods, instead of teaching STEM disciplines as discrete subjects with teacher-directed worksheets and end of unit testing. More recently, Sengupta et al. (2019) contended that teachers should be offering students an enhanced understanding of STEM through a transdisciplinary lens. The transdisciplinary approach situates learning around real-world issues that students want to investigate and captures their attention and interest (Cianca, 2019). Ritchie (2019) stated that a shift with the current STEM curriculum to a transdisciplinary approach is required to meet future challenges. Teachers must authentically assess project-based, student-driven activities that engage students in solving real-world problems that require multiple perspectives and skills (Ritchie, 2019). Teachers need to adopt a cross-curricular transdisciplinary approach that encourages many curriculum disciplines within one project (Back et al., 2016; Caton, 2021). Teaching STEM subjects in a siloed manner (Zahradnik, 2018) does not allow for the real-world experiences students should be exposed to. Teachers need to recognize that cross-curricular methods will engender deep learning and increase the quality of learning while covering more curriculum over the time they have during the academic day. Teaching each individual curricular subject separately takes time; time is a limited resource in educational settings as there is only so much time during the school day and through the school year.

With the new *Grade 1-8 Mathematics Curriculum* (Ontario Ministry of Education, 2020) and the new *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022) teachers need to consider re-examining their teaching practices to incorporate the STEM teaching and the coding and computational thinking that is within these curriculum documents. Although more teacher PL is now being offered in mathematics through Ontario Ministry of Education funding for the 2023-2024 school year, STEM teacher professional learning is lacking. This study sought to address this need by offering teachers coaching as PL in a transdisciplinary instructional approach by combining multiple subjects (e.g., Mathematics, Science and Technology, and Language). The purpose of this study was to investigate the impact of coaching on Grade 4 to 8 teachers' practices and beliefs about transdisciplinary teaching methods that integrate language and literacy and the *Grade 1-8 Mathematics Curriculum* (Ontario Ministry of Education, 2020) and the new *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022).

Definitions of Terms

For the purpose of the current study, the term *Grade 4-8 teacher* refers to a teacher who is certified, licensed, and in good standing with the Ontario College of Teachers (OCT), and they have a full-time position in a publicly funded junior (Grades 4, 5, 6) or intermediate (Grades 7, 8) grade classroom. The teachers in this study are also referred to as *teacher participants.*

The widely used acronym *STEM* (science, technology, engineering, and mathematics) will be used to refer to the lessons and learning which teachers are undertaking in their classrooms. *Technology use* and *coding use* will be used to describe specifically what each teacher participant used related to instructional technology. This may include (but is not exclusive to) block coding programs, 3D modeling software, and robotics applications. In this project the "T" was largely digital based, other forms of technology were used but the focus was on the coding aspect with the teachers.

A *transdisciplinary approach* involves instruction moving beyond just blending together different subjects or disciplines; it is driven by real-life problems and challenges and captures student engagement through interest (Cianca, 2019; Slavinec et al., 2019). Gillis et al. (2017) discuss the work of Otto H. Schmitt, from the 1960s, in which he suggested that people need to think in transdisciplinary ways; accordingly, Schmitt proposed that the way to resolve disciplinary borders in academia was to facilitate the meeting and collaboration of researchers from diverse disciplines.

In this study the term *language literacy* refers to two main language curriculum expectations: the use of stories or texts (digital, science textbook, journal, book, or written word) to support literacy connections and to prompt STEM inquiry and application; and to help build foundational (oral and non-verbal) communication skills to be able to present STEM concepts accurately. The stories used were not explicitly identified as STEM instructional resources of or texts that were specific to STEM topics. The purpose of reading the stories was to engage students in thinking about STEM topics in a non-STEM literary context. The stories elicited questions and discussions about relatable content that illustrated for the students that STEM topics are everywhere and in their everyday life and that they need to be observant of their surroundings with regards to STEM. The STEM focused lessons including the language and literacy context were emphasized as cross-curricular by the STEM coach.

The researcher (Principal Student Investigator) and STEM coach are the same person in this study. As a STEM coach, she works with educators (classroom teachers, resource teachers, English Language Learner teachers, EAs, ECEs), administrators, and students. Her main role is to plan and teach how to integrate technology, coding and STEM into the classroom learning environment. She collaborates with teachers to help them grow their practices in these areas. Throughout Chapters 3, 4, and 5, the STEM coach is referred to as the *PSI/STEM coach*, except in direct quotes from the teacher participants who refer to the *PSI/STEM coach* just as the STEM coach. As the researcher and the facilitator of professional learning, there was an acknowledgement of the need to independently assume these two roles for duration of the study without bias; this will be further discussed in Chapter 3.

Research Question

Given the background to this study, the statement of the problem, and the ensuing purpose and rationale for the study, the following research question guided this inquiry: After participation in a professional development coaching model from transdisciplinary approaches for teaching STEM-Language Literacy education, how do Grade 4–8 teachers' instructional practices and beliefs change?

Theoretical Framework

The term *STEM* has been increasingly prevalent in Canadian educational discourse during the past decade (Shanahan et al., 2016). STEM education is an approach to learning that removes the traditional barriers separating the four disciplines (science, technology, engineering, mathematics) and integrates them into real-world, rigorous, relevant learning experiences for students (Vasquez et al., 2013). Improving STEM education is a global imperative as countries strive to improve the lives and prospects of their citizens (Gess, 2017). John Dewey (1938) in his book *Experience and Education* promoted the idea of developing authentic and engaging learning experiences as the best way to utilize instructional time. Williams (2017) references Dewey's thinking that "children … will be solving problems through hands-on approaches" (p. 93). Dewey contended that all students should be interacting with their environment and learn best from hands-on experiential learning. When applied in a STEM education context, this implies that teachers need to accept that the curriculum (what we teach) and the pedagogy (how we teach) must be reformed with a STEM emphasis to be fully implemented (Jacobs, 2022).

With pervasive recognition that the STEM curriculum helps children better prepare for forward-thinking careers and opportunities (Akerson et al., 2018; Cianca, 2019; Margot & Kettler, 2019), Canadian leaders have emphasized the importance of finding new ways to incorporate STEM thinking and teaching into classroom learning (Razi & Zhou, 2022). The potential positive outcomes are numerous as STEM education teaches students more than just mathematics and science principles. STEM education can connect scientific inquiry by formulating questions that can be answered through investigation to inform students before they begin the engineering design process to solve problems (Kennedy & Odell, 2014). In STEM education, there is an emphasis on practical application-based learning that fosters the development of a variety of skill sets, including creativity and 21st century competencies (Stehle & Peters-Burton, 2019).

However, putting STEM education programs into action has proven to be more difficult than expected (Caton, 2021). Why? Teachers need to have a deep understanding of the content they are teaching (Shulman, 1987). Specific to the present study, teachers need to be adequately introduced to the advancements in the STEM discipline areas and become aware of changes in other related fields (Honey et al., 2014). Moreover, teaching involves more than just knowing the content area subject matter, it requires an integration of this content knowledge and pedagogical knowledge to create meaningful learning experiences for students (Shulman, 1987). Thus, teachers need to have strong PCK (pedagogical content knowledge) to be able to explain complex concepts, anticipate and address misconceptions, and provide appropriate instructional materials and strategies. As well, teachers with strong TCK (technological content knowledge) can reframe and present content in ways that are more comprehensible to learners through the use of technology. This is important when requiring teachers to step into teaching STEM with literacy with a cross-curricular and transdisciplinary approach.

Relevant to the current study is an application of the TPACK model (Mishra & Koehler, 2006) with the integration of technology in STEM education. For example, teachers require PK (pedagogical knowledge) and CK (content knowledge) in the form of coding language. Studies measuring teachers' technological, pedagogical, and content knowledge (TPACK) have shown that when teachers are confident in their pedagogical knowledge (PK), they are less confident in their technological knowledge (TK) (Hill & Uribe-Florez, 2020). The TPACK framework (Mishra & Koehler, 2006) provides a useful gauge of the learning environment and the interaction among pedagogy, technology, and content knowledge (Goradia, 2018). Figg and Jaipal (2012) derived the framework of TPACK-in-Practice from the TPACK model (Mishra & Koehler, 2006) and the PCK model (Shulman, 1986). One of the stages of this framework of TPACK-in-Practice positions teacher participants as learners in a technology-enhanced activity, allowing teachers to learn with the specific technology to meet content outcomes (Figg & Jaipal, 2012). This "modeling a technology-enhanced activity type (learning with the tool)" provided seamlessly integrated content with the technology tool (Figg & Jaipal, 2012, p. 4685). As a function of this model, teachers have the skills to teach authentically using the technology that they have practiced on (Figg & Jaipal, 2012). Teachers need to be experts with their content and pedagogy while strengthening their technological confidence.

Teacher self-efficacy is the level of confidence teachers have in their own ability to help students learn, build effective lessons and experiences for their students, and positively impact student learning (Gkolia et al., 2014). Bandura's (1987) theory of self-efficacy has important implications for STEM teaching and for teacher PD in STEM subject areas. Building and nurturing teacher self-efficacy (Bandura, 1987) in STEM education should lead to improved teaching practices, increased student engagement and achievement, and a more positive learning experience for students (Gardner et al., 2019). Sustained duration PD and STEM pedagogy learning can increase teacher self-efficacy (Zhou et al., 2023).

As coaches consider how to work with teachers in professional learning settings, coaches can apply Vygotsky's socio-cultural theory of learning and development which emphasizes the importance of social interaction and collaboration in the learning process (Vygotsky, 1934/1991). Coaches might focus professional learning within teachers' zone of proximal development (ZPD) with respect to their knowledge about STEM-Language Literacy with a cross-curricular and transdisciplinary approach. Coaches might model effective STEM-Language Literacy lessons within teachers' classrooms and then scaffold teachers while they co-teach subsequent lessons and offer them feedback. This provides coaches with the opportunity to gradually release responsibility (Pearson & Gallagher, 1983) to the teachers and support their professional learning. In this way, coaches and teachers are engaged in collaborative learning through social interactions while coaches provide the environment required for the growth and development of teachers. Coaches need to implement effective practices, establishing trusting relationships and listening to teachers' self-determined professional learning goals (Knight, 2007). Working with the teachers in such a collegial and collaborative partnership improves both teacher and student learning (Knight, 2007).

Significance of the Study

The significance of this study is that it identifies how teachers' practices and beliefs might change when they are coached in PL sessions focused on transdisciplinary approaches to STEM-Language Literacy education. Teachers engaged in designing lessons and projects that connected concepts from multiple disciplines promoting a more holistic and interconnected understanding of the subjects and of real-world challenges. By emphasizing real-world applications of STEM, teachers learned how this might help their students see the practical value of what they are learning while enhancing student engagement and motivation. Student-directed learning encouraged students to think critically, collaborate, and problem-solve, while the teachers realized that one can cover the curriculum expectations when facilitating the cross-curricular inquiry-based approach rather than single subject lessons. This study illuminates how teachers might see how to shift towards this inquiry-based approach to have students asking questions, exploring topics more deeply and discovering knowledge. The significance of this study resides in how it supported teacher professional learning to provide students with more opportunities for STEM rich learning.

Chapter Summary

A change in the way teachers practice their day-to-day delivery of STEM curriculum content in their classrooms is timely to explore. Teachers continue to be overwhelmed by the number of responsibilities they have within the classroom, including how to teach all the expected curriculum in a set amount of time. In Ontario, elementary teachers have been given a new curriculum in *Mathematics* (2020) and *Science and Technology* (2022), with little pre-release support and training. The *Grade 1-8 Science and Technology Curriculum* (Ontario

Ministry of Education, 2022) also supports cross-curricular lessons making suggestions for curriculum expectation links that teachers could use in their teaching. Clearly, there is a call to support teachers' practices implementing these recent curricula at a time when transdisciplinary learning for students is integral. The purpose of this study was to investigate the impact of coaching on Grade 4 to 8 teachers' practices and beliefs about transdisciplinary teaching methods that integrate language and literacy and STEM instruction. Chapter 2 offers a review of the literature on STEM education practices, the transdisciplinary approach, and coaching as the context and focus for this project. Chapter 3 outlines the methodology related to the five professional sessions that the teacher participants engaged in with the STEM-Language Literacy coach and the data collection and analyses. Chapter 4 presents the findings of the research and finally, Chapter 5 discusses these findings and implications for theory, future practice, and research.

CHAPTER TWO: LITERATURE REVIEW

This chapter will begin with a description of STEM (science, technology, engineering, and mathematics) in education and make distinctions among STEM education, STEM literacy and simply, literacy. Next, there will be a review of teachers' instructional practices in STEM. In parallel fashion, there will be a summary of the literature related to teachers' beliefs about STEM and cross-curricular teaching. Finally, given the focus of this present study, there will be a presentation of background research related to coaching with an emphasis on transdisciplinary STEM and coaching.

What Is STEM Education?

As previously noted, the term *STEM* is an acronym for science, technology, engineering, and mathematics. At times, reference to STEM is simply a way to discuss the four disciplines it stands for (Marrero et al., 2014), however, it is important to authentically honor the integrating of the fields of STEM (Morrison & Bartlett, 2009). Over the past 10 years, this term has been used in international discourse in education, industry, and innovation (Kelley & Knowles, 2016). Recently, the derivative term STEAM has evolved to include the arts. For the purpose of this thesis, STEM will be the focus.

There is a demand for STEM education (Akerson et al., 2018) as world-wide technology use continues to grow and to prepare our students for their future careers, educators must be effectively teaching STEM. Accordingly, STEM education has received a lot of attention in recent years and has emerged as a critical field of research all over the world (Takeuchi et al., 2020). An exemplification of this is the current *Ontario Grade 1-8 Science and Technology Curriculum* calls for technology integration and STEM skills such as coding (Ontario Ministry of Education, 2022).

There is a lack of consensus on how STEM education should be translated into practice (Siegel & Giamellaro, 2019). Shanahan et al. (2016) discussed how STEM integration could be conceptualized with what could be termed a boundary object. By definition, boundary objects are very ill structured and not well defined (Shanahan et al., 2016). These authors go on to point out that the experience of learning STEM in an integrated manner could provide for deeper and richer understanding than simply learning the multiple disciplines individually (Shanahan et al., 2016).

Prior research has examined the experience of teachers within the individual STEM disciplines (Dare et al., 2019). However, given that there is now an increasing expectation for STEM education in schools, teachers with non-STEM backgrounds are expected to facilitate integrated learning in STEM (Johnson & Sondergeld, 2015). Many educational jurisdictions have reported difficulties in achieving student success in STEM fields and they relate these difficulties to teachers' lack of expertise on how to teach STEM subjects (Stehle & Peters-Burton, 2019). In sum, “Preparing all teachers to enter classrooms to teach in and across STEM and non-STEM disciplines will require much work in rearticulating teacher preparation to align with the needs of a changing global society” (Jenlink, 2013, p. 178).

STEM Literacy Versus Language and Literacy

What does it mean to be STEM literate? STEM literacy has two different meanings, the first is concerned with the mastery of the STEM concepts and processes (Impey et al., 2012) and the second considers the scientific language skills (Webb, 2010). STEM literacy refers to the integration of STEM disciplines and the tools and knowledge necessary to apply STEM concepts to solve complex problems (Hull et al., 2011). This includes the language from the four STEM disciplines and understanding how to apply it to real-world problems and situations. Interestingly, some STEM teachers have been resistant to teaching language and literacy skills during science as they argue their role is to teach the curriculum (i.e., science and math), not language and literacy (McCoss-Yergian & Krepps, 2010). For the purpose of this thesis, the focus is on using language literacy in STEM, as a way to examine the instructional approaches and resources within the framework of inquiry.

The International Literacy Association (n.d.) defines literacy as

> … the ability to identify, understand, interpret, create, compute, and communicate using visual, audible, and digital materials across disciplines and in any context. Over time, literacy has been applied to a wide range of activities and appears as computer literacy, math literacy, or dietary literacy; in such contexts, it refers to basic knowledge of rather than to anything specific to reading and writing. (Literacy Glossary section)

Students with strong language and literacy skills are able to seek out information, explore subjects deeply, and gain an in-depth understanding of the world around them (PISA, 2018). Language and literacy skills have the potential to open up learning opportunities for students especially when other curricular areas are integrated. For example, when reading a time-slip fantasy novel, students might do a character analysis, identify the hero’s journey, and then consider if there are any STEM connections. In this example, teachers would encourage students to look beyond just the English language arts skills (i.e., reading) and make cross-curricular connections with STEM (i.e., inventions at certain points in history). Integrating STEM with language and literacy might support students, from an early age, to think beyond just building a robot as a function of learning in engineering to develop a deeper understanding (or literacy) of how STEM is around us in the real world.

Teachers' Instructional Practices in STEM-Language Literacy

Teachers who have limited knowledge of the STEM content disciplines may feel they have little to contribute to STEM instruction in the classroom; this influences how they teach STEM (Margot & Kettler, 2019). Indeed, Honey et al. (2014) stated, "one limiting factor to teacher effectiveness and self-efficacy is teachers' content knowledge in the subjects being taught" (p. 7). Zeidler (2016) states that it is unrealistic to expect teachers to build their pedagogical content knowledge in each individual discipline area within STEM when they have limited time to do so. Teachers have expressed that it is challenging combining STEM pedagogical approaches with their usual teaching practices (Asghar et al., 2012).

Researchers and curriculum designers have found that teachers' perceptions of STEM education and how to teach it differ widely (English, 2016). These various viewpoints have made it difficult to know what to teach and how to teach STEM, which may be one of the reasons why students do not always have the desire or learn the necessary abilities to succeed in STEM careers (English, 2016).

For teachers to teach STEM effectively, there are a few instructional considerations that need to be in place. Teachers need to have deep content knowledge, a strong belief in innovative teaching strategies, a student-centered approach, and comfort with interdisciplinary learning (El-Deghaidy & Mansour, 2015). Initiatives which focus on engaging students in more STEM learning and activities, with the outcome of preparing these students for future career pathways and STEM jobs, must include advancing STEM understandings (Franco & Patel, 2017). To accomplish this, teachers must be adequately introduced to STEM within their subject areas as well as become familiar with how it relates in other subjects (Honey et al., 2014).

Research has shown some commonalities among schools implementing hands-on, inquiry and inventive thinking instructional approaches in STEM education (LaForce et al., 2014). These attempts to include curricular integration have translated into some teachers effectively focusing on problem solving, collaboration, project-based learning, and real-world applications (LaForce et al., 2014). However, curriculum integration continues to be challenging for teachers (McPhail, 2018), thus, professional development targeting instructional practices in STEM can educate teachers and effect change in their practices (Gardner et al., 2019).

Elementary teachers are under a lot of pressure to educate pupils for the 21st century by prioritizing STEM education while also teaching all students to read and write at highly proficient levels (Clark & Lott, 2017). For example, traditionally, science instruction did not include the teaching of literacy skills, however, there is a realization that research, reasoning, formulating a hypothesis, and collecting, analyzing, and evaluating facts all require oral communication, and reading and writing skills (Clark & Lott, 2017). Reading and writing skills can be utilized to assist scientific inquiry rather than taking the place of it when science literacy is viewed as a type of inquiry (Pearson et al., 2019). Teachers might consider how to maximize the affordances of STEM education to strengthen language and literacy skills and students would concurrently learn how to read and write within the STEM disciplines while conducting inquiry-driven activities.

Teachers' Beliefs About STEM-Language Literacy

For some teachers, especially those who do not have background knowledge in the disciplines of science, technology, engineering, and/or mathematics, the prospect of STEM education can be daunting. Elementary teachers in particular who have limited STEM experience may feel intimidated by the conceptual knowledge and practices of the STEM disciplines (Trygstad, 2013). Often, teachers who perceive that they lack content knowledge prefer to use a textbook (digital), viewing this as a strong pedagogical tool (Winch, 2019) but textbooks quickly become obsolete and are pricey to replace. Teachers at the early elementary school level are frequently under-educated in science while teachers at the secondary school level are under-educated in scientific-specific literacy instruction (Pearson et al., 2019). Why might this be the case? Beginning in preservice programs, the structure of teacher education virtually guarantees isolation between literacy and science preparation (Pearson et al., 2019) as many programs do not have offerings that integrate language and literacy and STEM. This can impede beginning teachers' exploration into such topics as engineering design, coding, and the use of technology (e,g., robotics). It is not surprising that research studies have shown that only a small portion of teachers feel adequately prepared or at ease teaching integrated STEM content (Guzey et al., 2014; Tuttle et al., 2016).

Bell (2016) reported that teachers' perceptions of STEM related content, their personal knowledge base, and their understandings involving that STEM knowledge, were intrinsically linked to how effective their STEM delivery was in their own classrooms. In fact, where the teacher's knowledge was lacking or deficient, the students' learning was limited by association

(Liu, 2020). Specifically, many teachers do not have the necessary knowledge to teach engineering content or practices despite realizing the value of engineering education (Guzey et al., 2014; Tuttle et al., 2016).

In general, teachers value the idea of STEM education, and it is their valuation beliefs that influences their willingness to change their instructional practices and engage with a more interdisciplinary STEM curriculum (Margot & Kettler, 2019). Yet, teachers also note that pragmatic considerations such as class timetabling/scheduling impedes or even prohibits the opportunities to engage in interdisciplinary STEM lessons (Margot & Kettler, 2019). When it comes to appreciating the different STEM disciplines and combining them in their lessons, teachers reported this was difficult and many still see the topics as separate (Margot & Kettler, 2019). Teachers who have received some introductory professional development still are uncomfortable implementing STEM activities into their classrooms (Herro & Quigley, 2017). Collectively, these beliefs have the potential to impact their STEM education practices and potentially student outcomes.

Over the past decade, there has been a significant amount of research centered on classroom technology within STEM. When it comes to using technology in the classroom, teachers tend to identify two types of barriers or constraints: external and internal (Ertmer et al., 2012). External constraints include the lack of resources and limited training as many teachers are still working in schools that lack enough technology for each student (i.e., a 1:1 ratio of devices: students). For these teachers, the effort to provide each student in a class with a device is insurmountable, so technology use is not seen as a priority. Beliefs about external constraints are also influenced by the perceived value of technology for student learning (Polly et al., 2010); some elementary teachers simply do not see it as their responsibility to use technology in the classroom to prepare students for their future as secondary school students.

Internal barriers include teacher attitudes and beliefs and teacher confidence and perceptions about students' knowledge and participation in the learning process. When confidence is lacking to problem solve or answer students' questions about the technology, some teachers feel the emotion of anxiety (Howard & Gigliotti, 2016). Simply expressed, "some people don't use technology because they are intimidated by it" (Ertmer et al., 2012, p. 429). As well, some teachers feel there is risk in experimenting and changing their instructional practices (Howard & Gigliotti, 2016). Similar to beliefs about confidence with technology, in many cases it takes some teachers a long time and lots of practice to feel comfortable with teaching skills such as coding (Mason & Rich, 2019). Contributing to this is the fact that most Ontario teachers have little knowledge of coding (Rushowy, 2016). Teachers' beliefs need to be examined as their students will often come into the classroom with more knowledge and skills than their teacher in topics such as coding. The teacher needs to feel comfortable with allowing students to lead learning in such topics as technology integration and for the teacher to facilitate while students teach each other how they have used the technology in their projects. The teacher should be learning how the technology can be used alongside the student, instead of always being a learning role model for their students.

Instructional Coaching

Throughout a teacher's career, they will require ongoing professional development (PD) and professional learning (PL). PD focuses on updating skills and addressing new knowledge required (Cherrington & Thorton, 2013). PD can be viewed as a one-time experience to learn or increase abilities within a skill set, but it is up to the teacher to continue to maintain newly acquired knowledge on their own. PL is sustained as the learning of new knowledge and skills through continuing to support the learning beyond a one-off workshop or webinar. When compared to PD, Cherrington and Thornton (2013) state that PL typically adopts a more constructivist approach.

Effective PD is required to assist teachers in learning and refining the instructional strategies required to teach with positive impact on student learning (Darling-Hammond et al., 2017). Teacher PD is regarded as an important factor in influencing the teaching profession's quality (Kyriakides et al., 2017) and contributing to a teacher being a lifelong learner. Educators are expected to keep current with the demands of a changing world and PD is one way to ensure students will be prepared for their futures (Caena, 2011). Optimizing teacher PD is essential for student achievement and teacher longevity (Caena, 2011). Yet, traditional PD group workshop sessions have been shown to be ineffective in providing teachers with the necessary knowledge, skills, and abilities to successfully implement new curriculum (Sparks, 2002). To this end, Caena (2011) argues that PL is also integral as it differs from PD in that it is integrated into the experiences of teachers becoming a more nuanced and effective construct.

Teacher PL continues to gain popularity as a critical way to enhance teachers' instructional practices that support the increasingly complex skills that students must learn in order to succeed in the 21st century (Darling-Hammond et al., 2017). Over a decade ago, Caena (2011) found an interrelationship between student achievement and teacher efficacy. Although indirect, when PL positively influences teacher self-efficacy, there are student benefits related to higher achievement (Caena, 2011).

In recent years, instructional coaching has been adopted as an approach for the facilitators of both PD and PL (Knight, 2019) and touted as the optimal model (Kise, 2006). The goal of instructional coaching is to improve teachers' instructional practices through job-embedded PL with the goal to promote student learning. Instructional coaching provides an excellent opportunity for teachers, both experienced and novice, to develop their practices and skills further alongside a coach colleague. Instructional coaches can buoy teachers’ confidence, build their skill set and provide them with strategies and connections which will encourage their continual growth in their profession (Stephens & Mills, 2014).

Instructional coaching is a way to support teachers in their professional learning journey by providing effective support in specific areas they identify or that are new and emerging for their practice. There are different ways to provide coaching support to teachers depending on their experience, context, time, and resources available. Keys to providing teachers with the skills they need to enhance their practice include coaches providing the concepts and theory underlying instructional strategies teachers are asked to learn, demonstrating instructional strategies for this learning, and then supporting teachers’ practices in their classrooms. Instructional coaching involves the coach partnering with the teacher with the goal to help the teacher improve their teaching and learning to, in turn, positively contribute to student outcomes (White et al., 2015). Teachers who actively engage in partnerships with a coach generally continue to practice what they learned from the coaching experience compared to teachers who have not received coaching support and only attended workshops (White et al., 2015).

The most important aspect of coaching is the establishment of a positive relationship between the coach and the teacher. Initial interactions are designed to foster relationships and may include activities such as discussing teacher needs, goal setting, and problem solving (Gallagher & Bennett, 2017). This relationship may be fostered over time but in some instances the first few minutes of interaction needs to make an impact of comfort. Gallagher and Bennett (2017) identified six principles of coaching for inclusion: prerequisite teachers’ receptivity; the process of building trust to collaborating and reflecting; working through the tension between knowledge and beliefs; garnering administrative support; acknowledging evidence of change, impact, and capacity building; and setting goals for the future of the coaching role. When it comes to a teacher’s receptivity, if the teacher is not initially receptive to coaching, this could be a barrier for their professional learning, therefore, establishing a collaborative relationship encourages the teacher to further their reflection. The process of building trust comes from the coach identifying the needs of each teacher and differentiating their approach to best support the teacher's needs. In doing this, coaches need to be aware of their own beliefs, presenting to the teacher as an equal partner in their journey and not the expert in the room. When support comes from school administration, coaches perceive that there is a shared vision. Capacity building and goal setting are integral to seeing and documenting progress with respect to teacher change and impact. Finally, looking to the future includes coaches acknowledging their own professional learning to extend to supporting their teachers. From this research (Gallagher & Bennett, 2017), it is clear how other types of coaches including a STEM-Language Literacy coach could follow these same steps when working collaboratively with teachers to understand their beliefs and practices and support their learning needs with STEM-Language Literacy education.

As part of building the coach-teacher relationship, the coach collaborates with a teacher to get a clear picture of where they are currently at with their content understanding and together, they identify the teacher's and class goals. Then the coach helps the teacher choose teaching strategies to meet these goals (Sutton, 2011). The way in which the coach approaches each coaching partnership is integral to the success of the coaching (Grierson et al., 2024). Coaching may involve the coach demonstrating in the classroom and then encouraging co-teaching with the eventual goal of being a gradual release (Pearson & Gallagher, 1983; Pearson et al., 2019) of the instructional facilitation back to the teacher. The coach can monitor and help with problem solving and support until the teacher's goals are met. An important part of the coaching process includes teacher reflection, goal setting for next steps and accordingly, the coach should remain involved and available to the teacher for future growth. Importantly, throughout the process, the teacher needs to feel listened to, valued, and that the coaching they are receiving is worth their time investment. The coach-teacher relationship is sustained by the coach's dependability and responsiveness to the needs of the teacher, and in turn, the students (Grierson et al., 2024). In this way, coaching can support collegial collaboration (Stephens & Mills, 2014) which can help teachers to build their confidence and support their students.

At the present time, in the Province of Ontario, there are immediate demands for elementary teachers to adapt their instructional practices in two STEM related curriculum areas: mathematics and science. Given that the Ontario Ministry of Education recently released an updated *Grade 1-8 Grade 1-8 Mathematics Curriculum* (Ontario Ministry of Education, 2020) and *Grade 1-8 Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022), this was a timely focus for this thesis research to explore how to support elementary teachers who have new curriculum implementation expectations in front of them. As well, the prospect remains for Ontario elementary teachers to continue to maintain practices on online learning platforms and navigating technology for virtual and classroom learning. Coaching in digital technology continues to be an area that requires teacher professional learning. Instructional coaches act as the bridge among the Ministry of Education, the school board, and teachers with regards to the curriculum and assessment implementation (Kho et al., 2019). With the constant changes in educational technology integration, it is important to establish a learning environment to support this complex professional learning, teaching, and learning system (Grierson et al., 2024).

Transdisciplinary STEM-Language Literacy Coaching

STEM education has the potential to bring about a change in classroom culture and curriculum as it aims to prepare today's students to tackle the challenges of our quickly changing world (Cianca, 2019). It is widely acknowledged that STEM education must assist students in developing critical thinking and problem-solving skills (Back et al., 2016). The individual subjects that contribute to STEM education, particularly science and math, are often taught within their own discipline in elementary school (Jacobs, 2022). However, the integration of these subjects provides the context for these disciplines to be studied with purpose and meaning in the real world (Cianca, 2019). There are three ways in which teachers could approach the instructional integration of these topics: multidisciplinary, interdisciplinary and/or transdisciplinary teaching (Back et al., 2016; Cianca, 2019; Sunarti et al., 2019).

Multidisciplinary approaches involve several different scientific disciplines (e.g., biology, chemistry, physics, and engineering) and instruction is focused on the perspectives of each of those disciplines. A multidisciplinary instructional approach might involve looking at curricular areas around a specific theme (e.g., oceans), but the learning gained in one subject area does not affect another area or discipline (Cianca, 2019). According to Rosenfield (1992) the process of knowledge building does not occur across multidisciplinary teams. While the multidisciplinary approach can include multiple disciplines, the solutions or perspectives are seen as parallel to each other (Back et al., 2016).

Interdisciplinary approaches include the practice of teaching across disciplines, usually through the use of a common theme, topic, or issue (Sunarti et al., 2020). A single disciplinary approach has limitations, mainly because it is concerned with the norms of that one specific discipline, ignoring the contributions of other disciplines to the issue or potential solutions. Interdisciplinary allows students to examine the same theme, issue, or topic from the perspectives of various individual disciplines. Interdisciplinary teaching is different from multidisciplinary teaching in that it requires the integration and synthesis of different perspectives rather than a simple consideration of multiple viewpoints (Sunarti et al., 2020). In this approach segregation of subject areas is less likely (Cianca, 2019).

Transdisciplinary approaches go beyond simply teaching across disciplines by utilizing common themes, topics, or issues that run throughout multiple courses (Cianca, 2019). Transdisciplinary necessitates cross-disciplinary collaboration to develop a cohesive curriculum in which students work together to solve multifaceted problems. Transdisciplinary teaching promotes creativity, collaboration, and intentionality (Back et al., 2016; Sunarti et al., 2020). Because it transcends singular or interdisciplinary knowledge and applies domain-specific knowledge within an integrated framework, the transdisciplinary approach supersedes multi- and interdisciplinary practices and is better suited to addressing complex, open-ended problems (Back et al., 2016). With the transdisciplinary approach, knowledge incorporation occurs from disciplines outside of STEM as well, such as from finance, marketing, social sciences, the arts, and non-academic fields (Back et al., 2016). In the transdisciplinary approach teachers facilitate their students' learning and extend their thinking to encompass how each discipline is present and has a role to play. Community building, support from coaches and promotion of a positive learning environment should encourage the transdisciplinary approach in STEM and encourage an innovative learning experience (Caton, 2021).

A transdisciplinary approach to teaching encourages balanced problem-solving across a wide variety of skill sets and knowledge (Winterman & Malacinski, 2015). Research indicates that teaching using transdisciplinary techniques (e.g., where a real-world issue is introduced and then collaboration among disciplines needs to create a cohesive curriculum for students to collaborate and solve this multifaceted issue) can be challenging yet given the conventional subject-area organizational structure of schools, this is to be expected (Quigley & Herro, 2016). The goal of a transdisciplinary approach is to prepare students to engage with the world's issues through using their innovative, creative, critical thinking, communication, and collaborative skills (Quigley & Herro, 2016).

There has been some documentation of the impact of transdisciplinary approaches to teaching STEM but with postsecondary students (Gillis et al., 2017) where the curricular components of STEM are typically taught in individual courses and the onus resides with professors to reach out to collaborate or provide transdisciplinary opportunities. This is a challenge due to the nature of how courses are set up within programs in post-secondary institutions; ironically, in K-12 education there are similar challenges. Caton (2021) although speaking to STEAM states that the transdisciplinary approach to teaching needs to become a discussion and method for innovative teaching and learning for both teachers and students. Yet, few research studies have looked at how elementary students respond to a transdisciplinary approach to teaching STEM (Back et al., 2016).

It is evident that enhancing teachers' instructional impact is essential for enhancing STEM learning and transdisciplinary learning opportunities for students (Lindvall, 2017). Yet, some PD facilitators report that teachers have been resistant to utilizing STEM instructional practices (Dare et al., 2019). To realize the implementation of integrated STEM education, PL should be designed with teachers' specific needs in mind, including pedagogy, content knowledge, and teachers' attitudes and beliefs (Copur-Gencturk et al., 2014). In Ontario, teachers are encouraged to learn to incorporate STEM instruction to align with the *Science and Technology* (Ontario Ministry of Education, 2022) and *Mathematics* (Ontario Ministry of Education, 2020) curriculum by introducing coding, engineering design, and other STEM topics. PD that is offered through one-off workshops needs to be supplemented with minimal pull-out professional development and as much coaching support as can be provided by STEM coaches.

The STEM coach needs to be knowledgeable in the STEM curriculum disciplines including coding and anchor strong relationships with the teacher participants through listening to the teachers and establishing a partnership (Knight, 2007). From the coaching experience, ideally, the teachers' practices and beliefs might shift to adapt their STEM instructional methods to the benefit of their students and prepare them for their future.

The current thesis research introduced grade 4-8 teachers to the concept of transdisciplinary STEM-Language Literacy through a five-session coaching partnership. During this time, teachers and students worked to solve a real-world problem engaging in the transdisciplinary approach rather than the current single subject delivery. An understanding of how the practices and beliefs of the teachers influenced their experience was documented, analyzed and presented along with future implications.

Chapter Summary

The current emphasis in education is to provide students with real-world problem-solving opportunities, which will prepare them for their future (Cianca, 2019). In response to the new Ontario *Grade 1-8 Science and Technology Curriculum* incorporating more STEM programming through inclusion of engineering design and coding (Ontario Ministry of Education, 2022) teachers will require support in delivering this content. Teachers are also feeling the pressure of trying to deliver the recent 2020 Ontario *Grade 1-8 Mathematics Curriculum*. Teachers require supports for their practice which may come in the form of working collaboratively with a STEM coach to help with their PL and delivery of this new curriculum. The STEM coach might follow the principles of effective coaching (Gallagher & Bennett, 2017) to ensure the needs of the teachers are met to facilitate best practices in STEM-Language Literacy education. A transdisciplinary approach could help cover multiple curriculum expectations while creating community partnerships and providing teachers with the means to facilitate real-world problem-solving experiences for their students (Back et al, 2016; Cianca, 2019). Overall, Chapter 2 aimed to review past research and apply it to the current study. The subsequent chapter will now outline the research methodology of the present study.

CHAPTER THREE: METHODOLOGY

This chapter discusses the methodology used for this study. The first section describes the project context, followed by the research methods and design of the study and finally the participants. The fourth and fifth sections outline the data collection and analyses and the ethical considerations. The methods outlined in this chapter addressed the following research question: After participation in a professional development coaching model from transdisciplinary approaches for teaching STEM-L education, how do grade 4-8 teachers' instructional practices and beliefs change?

Project Context

For this research study, the Principal Student Investigator (PSI) was also the STEM coach in a small-to-medium school district in Southern Ontario. As a STEM coach she developed a five-session transdisciplinary-focused STEM-L series of professional learning (PL) sessions for Grade 4-8 teachers. These were optional in-class coaching opportunities for these junior/intermediate (i.e., Grade 4-8) teachers and students. The STEM-L coaching sessions followed the transdisciplinary approach incorporating STEM, language and literacy, and the new *Grade 1-8 Science and Technology* curriculum (Ontario Ministry of Education, 2022) expectations with regards to engineering design process and coding, as well as mathematics.

The rationale behind this professional learning was trifold. Firstly, the chief goal was to help teachers build confidence with the *Grade 1-8 Science and Technology* curriculum (Ontario Ministry of Education, 2022) which includes STEM, engineering design process, and coding knowledge. Secondly, there was a goal to demonstrate that what teachers are already doing can be adapted and/or reinvented to satisfy the engineering design process while teaching transdisciplinary skills and including language and literacy in their STEM teaching. It is important to note that now in the *Grade 1-8 Science and Technology* curriculum (Ontario Ministry of Education, 2022) teachers need to be using the coding language and effectively include coding in STEM projects. Also, important to note that the *Grade 1-8 Language* curriculum (Ontario Ministry of Education, 2023) encourages cross-curricular and integrated learning. Thirdly, this PL project encouraged teachers to realize that curriculum does not need to be taught as individual disciplines as we introduced real-world problem-solving opportunities in the classroom for students to engage in. The PSI gathered data during and on the PL program to identify strategies related to how transdisciplinary teaching can support STEM with language and literacy and coding.

Methodology and Method

The philosophical underpinnings of the PSI's approach included pragmatism. Pragmatism as a philosophy provides a framework for conducting studies that prioritize real-world application with the achievement of practical outcomes (Dewey, 1938). In pragmatic research, the research question itself takes precedence over the theoretical; one can select the best way to address the question as there is flexibility (Creswell, 2013). Flexibility and adaptability allow for modification of the approach when circumstances change or there is an evolution of insight.

The methodology used for this project was the generic descriptive interpretive qualitative (GDI-QR) approach (Elliot & Timulak, 2021). In this approach, the study attempted to understand how people construct, interpret, or derive meaning from their experiences and the world around them (Kahlke, 2014). Frequently, researchers encounter research questions that do not necessarily fit within the confines of a single established methodology; generic studies allow researchers to experiment with these boundaries, use the tools that established methodologies provide, and develop research designs that fit their epistemological stance, and specific research questions (Kahlke, 2014). Because its data can typically be restructured as quantitative to connect to the statistical side of the investigation, the general qualitative approach is well suited to use in mixed methods studies (Creswell, 1995). The advantage of using GDI-QR is its ability to focus attention on the activities of collecting and analyzing data, providing a flexible framework for qualitative research to adapt sets of strategies and procedures that fit the work, and providing clarity about the role of theory in the research (Elliot & Timulak, 2021). The disadvantage of this method within the GDI-QR approach is that some researchers find the freedom too open (Elliot & Timulak, 2021). For this project, GDI-QR was used to gain deeper insight into the practices and beliefs of the teacher participants. The teacher participants were at the centre of this research and the flexibility of this approach allowed for the variety of data collection methods being used; this perspective might offer a guide for future research.

Participants

Teacher participants were certified by the Ontario College of Teachers (OCT) and employed by the participating small-to-medium Southern Ontario school board. These teachers were in full-time positions and teaching in the junior (Grades 4-6) or intermediate (Grades 7-8) divisions. Teacher participants were responsible for teaching the subjects of science, mathematics, and language within their own classes; the classes were not on subject rotary. The teacher participants all self-identified as having limited coding experience within the context of the new *Grade 1-8 Science and Technology* curriculum (Ontario Ministry of Education, 2022) and were open to receiving professional learning support from the PSI/STEM coach. The PSI/STEM coach typically has a caseload of approximately 350 junior/intermediate teachers. Ten junior/intermediate (Grade 4-8) teachers from this caseload were chosen from a random name picker and invited to participate (see Appendix A). Of this group of invited participants, seven teachers volunteered to participate (see Appendix B); however, one teacher did remove herself from the project due to personal family matters and a leave of absence from classroom teaching. Table 1 presents the profiles of the six teacher participants, including their self-evaluated STEM experience.

Table 1

Profiles of Teacher Participants

Teacher participant	Years of experience	Grade teaching	STEM experience (self-evaluated)
AP	24	6/7	Intermediate
AM	10	7/8	Intermediate
AL	18	6	Beginner
AK	18	7/8	Beginner
CW	22	8	Intermediate
TK	10	4/5	Beginner

The PL sessions are described next that were replicated in each of the teacher's respective classrooms by the PSI/STEM coach.

Professional Learning Sessions

Starting in February 2023, the participating teachers were contacted to schedule and receive five professional learning sessions/phases with the PSI/STEM coach. The teachers requested the dates that worked for their class scheduling and school scheduling. One participating teacher had her sessions in March, the other five all scheduled for May. These sessions were provided regardless of whether the participant agreed to all the forms of data collection. All six of the participating teachers remained in the professional learning project for its entirety and no one withdrew from the data collection within the duration of the professional learning project.

Session 1 involved the teacher and the PSI/STEM coach collaboratively planning. The teacher was asked to share where they would like to be with their STEM curriculum knowledge, as well as if they were open to connecting their language and literacy curriculum to their STEM lessons. The teacher and PSI/STEM coach identified what strands of STEM the teacher was comfortable with in the *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022) and *Grade 1-8 Mathematics Curriculum* (Ontario Ministry of Education, 2020) and where spiraling of strand (between the curricula) work could occur. This began to open up the concept of overlapping the disciplines and led to the defining of the transdisciplinary approach. Discussion regarding a transdisciplinary approach helped to clarify STEM expectations as the teacher and PSI/STEM coach decided on the real-world problem-solving opportunity they would then present to the students. Language literature (texts) possibilities were suggested by the PSI/STEM coach. Often, these text selections had an Indigenous theme, but were not specifically STEM books. The idea was that teachers would see how using any literature could bring awareness of STEM within it as well as have the teacher recognize the importance of students integrating language and literacy into STEM. The next session dates and topics for professional learning and instructional planning were selected during Session 1.

Session 2 involved the PSI/STEM coach introducing the storytelling/literacy component to the teachers' class of students with an interactive hands-on exploration lesson. Examples of the stories used are: The Eagle Feather Story (Prince, 2020), Where Wonder Grows (Gonzalez, 2021) and We are Water Protectors (Lindstrom, 2020) This began with a text reading that prompted teacher and student discussion of the STEM topic within the story, as well as the real-world overlaying message. The purpose of this session was to demonstrate to the teacher and the students that STEM is everywhere and to increase their heightened awareness of this. Ideally, students would then be able to link their STEM knowledge to aspects in literature (e.g., stories, news articles, web posts). The hands-on exploration aspect of the lesson was a science-based experiment which demonstrated principles being considered from the texts. For example, one story was about an eagle interacting with animals, from an Indigenous perspective. The main theme of this story was respect and integrity. It featured an eagle and the eagle feathers, along with various forest animals. From the STEM standpoint, students discussed the flight of the eagle and the importance of the feather structure. They then created and modified flying gliders for the purpose of seed dispersal in areas that would benefit from drought resistant plant growing to stop erosion. In a second example, students listened to the same story of the eagle, however these students were learning about structures. The students quickly identified the purpose of the pit house in the story and how this was an Indigenous structure. They also spoke of the importance of the structure of the eagle feather with regards to air flow and movement. The students then began thinking about how in the eagle story there were other animals that were helpful based on their various abilities. This led to discussion about helping each other and how different people have accessibility needs. From there students were able to brainstorm and design using the STEM materials (e.g., tubing, syringes, cardboard, robots, building kits) of hydraulics and pneumatics to help people with different needs.

In Sessions 3 and 4, the PSI/STEM coach worked with the teachers to present the students with the engineering design process and coding sessions to support the student-negotiated projects. These were extensions from the hands-on experiments students were engaged in during Session 2. During these sessions the teacher and the PSI/STEM coach facilitated the learning in a partnership. Students had negotiated a real-world problem to solve using engineering design, constructing prototypes that included non-digital technology (eg. hydraulics, motors, pneumatics, ramps). During the process of construction coding of robots, building of robots and coding of microbits were scaffolded by the PSI/STEM coach teaching the whole class some revision coding and then working, with the teacher, at each group to troubleshoot coding needs. In two cases the teachers were fully co-teaching with the PSI/STEM coach. In the other four cases, the teachers were learning alongside their students. While students were working, the teacher and PSI/STEM coach were looking at assessment and evaluation for the tasks the students were working on.

In Session 5 the teacher and the PSI/STEM coach concluded the coaching sessions. The activities within the teachers' classes were still ongoing with the student-led projects. All six of the teachers decided to provide additional class periods for the students to complete the project. During Session 5, the PSI/STEM coach and each of the teachers debriefed together and discussed the next steps for the teacher to repeat the process in the future. During each session, the PSI/STEM coach communicated with the teacher and listened to any inquiries the teacher had regarding implementing strategies to integrate literacy and coding into STEM transdisciplinary teaching. The PSI/STEM coach also helped the teacher establish a tool for assessment in the form of a cross-curricular rubric, reviewing what expectations were going to be met by the students' projects in the various subject areas. After the sessions, a follow-up email from the PSI/STEM coach was sent to thank the teacher and offer continued support and any extra resources the teacher may have asked for. Table 2 presents a summary of the five sessions, activities, and participants involved.

Table 2

Summary of Sessions, Activities, and Participants

Session no.	Activities	Participants
1	– Conference with teacher – Build relationship – Establish goals for teacher and for students – Book Sessions 2-5	PSI/STEM coach Teacher participant
2	– Meet students – Introduce language literacy; read story and discuss, draw out the STEM in the story with student participation – Run hands-on inquiry lab with students to follow up on concepts from story	PSI/STEM coach Teacher participant Students
3	– Co-teach with teacher: introduce students to engineering design process – Students begin leading their design teams/exploration/coding	PSI/STEM coach Teacher participant Students
4	– Continue teacher learning and facilitation of student-led inquiry projects	PSI/STEM coach Teacher participant Students
5	– Continue teacher learning and facilitation of student-led inquiry projects – Debrief with teacher and plan next steps; more class time to complete, assessment goals and tools	PSI/STEM coach Teacher participant Students

Data Collection and Analyses

There were four types of data collected: pre-questionnaires, interviews, researcher reflections and fieldnotes, and artifacts. It is worth noting that in Spring 2022, a pilot project was run in which pre- and post-questionnaires were administered to 10 teacher participants. These questionnaires were modified to apply to the current project. Also, during the pilot study, three teachers were interviewed; the interview protocol was also modified based on this experience. In this way, the pilot project's data collection instruments and procedures served to provide a degree of veracity for the present study's data collection procedures and the types of data collected. Ethics approval was received by the school board and the university for the pilot study to proceed.

Pre-Questionnaires

Prior to Session 1, the first form of data collection asked the participants to complete a Pre-session questionnaire as a Google form (see Appendix C). This questionnaire asked teachers about including literacy into their STEM lessons, their comfort with STEM, their understanding of the engineering design process, and their experience with teaching coding. This questionnaire was completed by the participating teachers on their own time and on a private device. Each teacher had 1 week to complete and submit the questionnaire responses. The responses were downloaded automatically into a spreadsheet in the PSI's personal (password protected) account.

Interviews

At the conclusion of Session 5, the teachers were invited to participate in two post-session interviews (10-15 minutes in length each) at their convenience. The interviews were conducted using MS Teams, Google Meet, or in person at the school of the teacher, in a semi-private area (e.g., teacher's classroom when no students are present). The interview responses were audio recorded to the questions in Appendix D. The first interview was regarding the practices and beliefs of the teacher participant during the coaching sessions and this interview was conducted by the PSI/STEM coach; this first interview is referred to as "Interview" in Chapter 4. The second interview focused on the teacher participants' impressions of the PSI/STEM coach's coaching strategies and methods. This interview was conducted by the PSI's Thesis Supervisor as per REB Committee request and is referred to as "Post-session Interview" in Chapter 4. Teachers received the transcript of their interview responses and were asked to go through the transcript and approve of what was recorded (or request that any portion of their responses be removed or not analyzed). All six teachers approved of their transcriptions for their two interviews to be used in their entirety.

Researcher Reflections and Fieldnotes

The PSI/STEM coach recorded reflections after each session on her computer as open-ended notes. These reflections were made to document how she was exploring the tensions between the roles as the PSI researcher and also the STEM coach. These reflections also described what the PSI observed with regards to teacher-coach relationship and how this would be a call to action for the STEM coach. In these reflections she strived for objectivity.

During the sessions, the PSI/STEM coach also documented observations of the meetings with the teachers using open-ended fieldnotes and/or capture images of the work being done. The impressions of the students' work was from the perspective on the teachers' reflections, as ethics approval for reflections on what the PSI/STEM coach was seeing and doing as a coach with the teacher. The PSI had 30 fieldnoted sessions.

Artifacts

After each of the five sessions, the teachers were asked to send the PSI/STEM coach artifacts such as lesson plans, collaboratively developed rubrics, and any evidence of teacher–student interactions from the transdisciplinary lessons. This was evidence of the teacher's practice and professional learning. These artifacts were not student-produced and did not have any identifying information related to students.

Data Analyses

Data analyses was conducted manually. The pre-questionnaire, the transcripts of each interview, the researcher reflections, and fieldnotes were downloaded to a secure Google drive folder as Word files. Each Word file (i.e., pre-questionnaire, interview transcripts, researcher reflections, fieldnotes) was first carefully read and reviewed by the PSI. During this first read, the PSI began to identify commonly used language and expressions among the participants by creating a summary list of these words and phrases. Examples of these expressions included words and phrases such as: "structure, lesson plans, not 'techie,' do not feel comfortable with coding, need more coach time, surprised at student motivation, what about marks for this," and questioning if there will be enough time.

Discussion then took place between the PSI and her Supervisor with regards to the language and expressions being identified within each of the files and the trends that these might be suggesting. For example, they discussed how teacher participants were all concerned about how the sessions and students' work would be assessed. The PSI and Supervisor also discussed how to differentiate when a teacher participant was expressing a belief versus when they were referring to their practice. From there the PSI began coding each form of data by highlighting recurring ideas/concepts in all of these forms of collected data (Creswell, 2013). Through this interpretation of data by coding analysis, the PSI utilized descriptive words and expressions, using the participants' own words to support the interpretations (Creswell, 2013). Examples of highlights include: teacher participant expression of confidence with regards to teaching STEM and the new *Grade 1-8 Science and Technology Curriculum* (Ministry of Ontario Education, 2022), the participants’ apprehensions with not being the expert or knowing how to code, their understanding of cross-curricular and transdisciplinary approaches, their structured siloed teaching, practices and how they changed as they saw the transdisciplinary approach in progress, beliefs and surprises as they witnessed students motivated and engaged, expressions of apprehensiveness regarding being able to assess what students were working on. In total there were 266 codes from: the six teacher participants’ pre-session questionnaires (six codes); 30 session fieldnotes (68 codes), and 12 post-session interviews (192 codes). It became apparent that there were three main categories that the participants were all expressing: their instructional practices related to STEM-Language Literacy, what they believed about STEM-Language Literacy instruction, and the activities and interactions they were having with their STEM Coach.

Next, the PSI clustered the codes into these three main categories using three colours that highlighted the commonalities (Nowell et al., 2017) being expressed by each participant to allow for clarification of actions and beliefs of participants and interactions with the STEM coach. The broad categories were labeled by the PSI and her Supervisor as: teacher practices, teacher beliefs, and coaching interactions. As the PSI went through the coded data, the PSI met virtually with her supervisor to verify the categorizing process, to ensure the proper highlighting was taking place and that the coded data were categorized reliably.

Then the PSI and Supervisor collaborated to examine the three main categories and describe them as meaningful themes and sub-themes that would respond to the research question. In particular, there were thematic findings that elaborated on the teachers’ practices related to the way they structured their teaching time, their traditional lesson format as well as their practices with teaching new or unknown topics. There were findings that described the teachers’ beliefs about what they wanted to project to their students, being the expert in the room, how students would work in a new student-directed lesson, the amount of time they would dedicate to the lessons. Finally, there were findings that elaborated on the participants’ impressions of the coaching interactions between them and the STEM Coach. The PSI identified evidence that the themes were clearly supported from the data (i.e., pre-questionnaire, interview transcripts, researcher reflections, fieldnotes) by selecting quotes that illustrated each theme. Attention was paid to provide evidence demonstrating the commonality of occurrences across the six teacher participants. Table 3 presents samples of data coding.

Table 3

Example of Coding for Quotes From Data: Theme and Sub-Theme Identification

Quote	Theme	Sub-theme (look fors)
"I need to get Flight completed before May"	Instructional practice	Teacher started with very structured practice
"I've grown so much in the coding and digital area…"	Beliefs	Teacher conceptions of their abilities
"… the way we collaborated together. The STEM Coach listens and appreciates my knowledge, then helps me go further."	Coaching practices	Working relationship

Trustworthiness and Credibility

Trustworthiness and credibility are crucial concepts that pertain to the validity of the research findings. According to Creswell (2013), ensuring trustworthiness and credibility is essential in qualitative research to enhance the overall quality and confidence in the research outcomes. Credibility speaks to the believability and truthfulness of the research findings. To enhance credibility the strategy of triangulation was deployed. Triangulation, using multiple data sources, methods, or researchers to examine the same research findings from different angles, helps to corroborate the findings and reduce the impact of bias or subjectivity on interpretations (Creswell, 2013). In this research the four types of data (i.e., pre-questionnaire, interview transcripts, researcher reflections, fieldnotes) were used, as well as communication, self-checking, and verification with the PSI's Supervisor to strengthen the validity and reliability of the findings.

Ethical Considerations

This study was granted Ethics Clearance by both Brock University's Research Ethics Board (see Appendix F) and the school board's Research Ethics Review Committee (not included herein to maintain anonymity and confidentiality). Participating teachers could withdraw at any time by indicating so to the PSI. Teachers were reminded that there were no consequences to withdrawing from the research at any point during the PL sessions and data collection. This information was clearly stated on the consent form and was verbally communicated to participating teachers before commencing with data collection.

Chapter Summary

In summary, this project involved six teachers and their classes from the small-medium school district in Southern Ontario who all were teaching in the junior and/or intermediate divisions (Grade 4-8) at their respective schools. These teachers engaged in five sessions with the PSI/STEM coach during which time they worked to plan, design, and facilitate a STEM and literacy program where teachers learned to work with a transdisciplinary approach to curriculum delivery. Using the generic descriptive interpretive research method, data were collected in the form of pre-questionnaires, fieldnotes, researcher reflections, artifacts, and a two-part interview (one with the PSI and one with the PSI's Supervisor). Data were analyzed by first identifying common teacher participant statements and expressions. A summary list was made and then the PSI coded these statements and expressions paying close attention to the meaning of them. The codes were then delineated by three colours to differentiate the categorical clusters. The three broad categories that were then developed into themes were: teacher practices, teacher beliefs, and coaching interactions. A selection of pertinent quotes was used to provide evidence for the themes. These themes and the quoted evidence will be elaborated further in Chapter 4.

CHAPTER FOUR: FINDINGS

This chapter presents the findings that respond to the research question: After participation in a professional development coaching sessions from transdisciplinary approaches for teaching STEM-L education, how do Grade 4-8 teachers' instructional practices and beliefs change? The chapter is divided into three main sections that describe the changes in the teachers' instructional practices and beliefs as well as salient PSI/STEM coaching interactions. The first section, Changes to Teachers' Instructional Practices, includes the sub-themes: Started With Structured Practices; Shifted to Inquiry-Based, Student-Directed Learning; Increased Student Motivation and Problem-Solving; Need for More Coaching Time; Learning Coding Alongside Students; Cross-Curricular, Dynamic Assessment. The second section, Changes to Teachers' Beliefs about STEM, includes these sub-themes: Varied Conceptions of Teaching Language and Literacy in STEM; Initial Apprehensions Shifted to Realizations; Reservations About Accountability Related to Transdisciplinary Learning; Transdisciplinary Learning Impact on Students. The final section, PSI/STEM Coaching Practices, includes the sub-themes: Good Working Relationship; Coach Is Flexible and Open; Listening to and Meeting Teachers Where They Are; Gradual Release of Responsibility: Extending to the Next Level.

Changes to Teachers' Instructional Practices

This first section includes the six sub-themes: Started With Structured Practices; Shifted to Inquiry-Based, Student-Directed Learning; Increased Student Motivation and Problem-Solving; Need for More Coaching Time; Learning Coding Alongside Students; Cross-Curricular, Dynamic Assessment.

Started With Structured Practices

Part of the coaching role involves identifying quickly with the practices or routines that teachers include in the day-to-day structure in their classroom. In this study, the PSI/STEM Coach drew on her professional experience and often noted that she has worked with many teachers who were using teacher-directed or structured pedagogies - the six teacher participants in this study were also initially using these types of pedagogies. The PSI/STEM Coach reflected on her observations that the teacher participants had lesson plans that included many teacher-directed actions and only a few moments throughout the day that would allow for students to do some exploratory learning. Based on this lived professional experience, the PSI/STEM Coach began working with the teachers during Session 1 by proposing full lessons which were predominantly student-directed. The PSI/STEM Coach asked the teachers about their expectations for the coaching sessions and what curriculum expectations teachers were looking to focus on. The teachers replied similarly, expressing that they wanted to focus on one strand of the *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022) and to complete the lessons in a 2-week period. This was reflective of the structure of their long-term plans, whereby they had indicated that a specific Science strand would be completed by a particular date and within designated times during the school day. For example, a teacher stated, “I need to get Flight completed before the end of May” (Fieldnote, AL March 4, 2023). Another teacher stated, “I’ll be in Strand D [Structures and Mechanisms] and want to get it done so I can fit Strand E [Earth and Space Systems] in before report card marks are due” (Fieldnote, CW March 4, 2023). The PSI/STEM Coach noted in her fieldnotes, “Teachers are working by Strand, not spiraling or integrating cross-curricular, this could be contributing to the pressures to get things done and not spending time exploring and enjoying the STEM, as they are on a report card deadline” (Fieldnote, March 4, 2023).

Given the expressed expectations of the teacher participants, the PSI/STEM Coach was able to work with their preferred strands in the *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022) such as Strand D [Structures and Mechanisms], Strand E [Earth and Space Systems] and Strand A [STEM Skills and Connections]. For most of the teachers, the timing of addressing these strands was dictated by their requirement to produce grades in these Science strands instead of being motivated by the potential student experience. The PSI/STEM Coach attempted to include in the PL sessions beginning practices that would integrate cross-curricular subjects while introducing the teachers to the concept of transdisciplinary teaching. The PSI/STEM Coach centered discussions in Session 1 on a theme and real-world application for the concentration (i.e., Strand) that teachers wanted to cover in the lessons. The teachers were hesitant but open to trying to focus on these applications as long as some assessment was guaranteed. “AK is very open to working in other subjects with the Science strand, just as long as she has marks at the end, she repeats this requirement a couple of times” (Fieldnote, March 4, 2023).

Inquiry and hands-on learning were discussed during the planning Session 1. All the teachers expressed that their typical lessons would follow a structure of introducing new concepts with a slide show, having students answer some questions, and maybe incorporating a demonstration of a principle or a lab. This was a very structured, teacher-directed form of teaching. It did, however, control the time needed to teach the concepts so the teachers' goals of finishing a strand within a set number of periods was possible.

Inquiry and hands-on learning were welcomed by the teachers, but there was a nervousness with regard to how much time inquiry-based methods could take. Also, there was a difference in the ways that inquiry was conceptualized by the PSI/STEM Coach and teachers. The former regarded inquiry as an opportunity for students to express an interest and then they were provided time and tools to discover the answers to their queries. The teachers expressed that inquiry and hands-on learning meant providing the students with a research question and asking them to look it up on the computer or have students follow a step-by-step procedure to build a model and then try it out. The PSI/STEM Coach quoted a teacher, CW who stated, "I had them follow my instructions and build this hydraulic pump. Then they could try it out" (Fieldnote, March 4, 2023). In another interaction, the PSI/STEM Coach took the following fieldnote:

> I have my students look up the answer to a question I give them, I need them to know this information so we cannot stray from the expectations, then they share what they learned in groups or as a jigsaw. (Fieldnote, March 4, 2023)

In this case, having students become experts and share through a jigsaw is a common instructional strategy, but this practice, the way the teacher described it, did not promote student-directed learning as it was dependent on teacher facilitation. There was still evidence that the teacher was at the front of the class directing what to do. In both of these examples quoted from the fieldnotes, the lesson and experience were clearly teacher-directed with the intent to expediently cover expectations in the *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2020).

During Session 2, the PSI/STEM Coach entered the physical classrooms of the teacher participants for the first time during the project. She noted that in five of the six rooms on the chalk/bulletin boards there was a daily schedule listing designating specific times for science and the other curricular subjects. This is a very organized way to let students know what will happen throughout the day and is particularly helpful for students on Individual Education Plans (IEPs) who need to know and anticipate transitions during the day.

An example of structured periods of time occurred during Session 2 in teacher TK's class, while the PSI/STEM Coach was reading a story and having students interactively discover the STEM concepts in the story. There had been an interruption during the period (due to a student behaviour) so the text reading was paused and then the period ended. The teacher immediately told students to move to the next subject. The PSI/STEM Coach asked if it would be possible for more time to explore the topic and the teacher did acknowledge maybe later in the day they could squeeze it in. “The rich student-directed learning that was occurring was interrupted by the need to stick to the schedule, rather than appreciating how engaged the students were and letting them conclude in a timely manner, they were shut off” (Fieldnote, May 23, 2023).

When working with all the teachers the PSI/STEM Coach asked them why their period timelines were so strictly adhered to and why some of them used the phrase “watch the clock” with the students. Teachers cited that they were focused on this subject scheduling to either ensure that they got in their Ministry of Education prescribed “math minutes,” or they had too much curriculum to get through and did not have time to “waste” on students doing a project. Teachers were not comfortable with borrowing time from other periods during the school day. The PSI/STEM Coach tried to explain that by working through the learning in a transdisciplinary way students would have a more significant opportunity to learn and would be covering other subject areas as well providing for a rich experience with all subject matter in a real-world application context.

> I try to explain and AP seems very receptive that rather than always trying to fit in all the curriculum separately throughout the school year, with transdisciplinary learning (cross-curricular) a real-world application could introduce and allow for multiple subject areas to be integrated into the lesson, enriching the experience as students would see how the math (for example) fits into the real world as they apply those skills and so on. (Fieldnote, May 23, 2023)

These discussions with teachers were to initiate teacher reflection on their practices and act as a catalyst for teachers to explore new approaches and evolve their instructional strategies. The PSI/STEM Coach sought to foster a more holistic learning approach that is not focused on getting activities done for the purpose of assessment and grading, but on engaging in the STEM-Language Literacy learning and growing the knowledge of each student.

Shifted to Inquiry-Based, Student-Directed Learning

As the PL sessions progressed, teachers began to acknowledge the benefits of having transdisciplinary topics and cross-curricular projects led by the students. Teachers began to feel comfortable with the process of the PSI/STEM Coach in the room modelling conversations with students while the teachers shadowed and then tried the conferencing and questioning on their own. "Yes, we could have read an article about hydraulics and pneumatics and how they work, but if you actually give them the experiences to use this in the real world, it was very applicable" (Post-session Interview AM, May 26, 2023).

One overarching reason for this shift was that all of the teachers started to see their students engaged in the learning process. This even applied to students who the teachers had originally felt would not function in a less structured environment, "They are so motivated. They love building something up and then having to take it apart and put in a different component and see if that works better" (Post-session Interview AL, May 24, 2023).

Teachers recognized the importance of authentic inquiry-based learning and came to understand how important their roles as a facilitator was rather than the role of being a director in the classroom.

> I think too watching the PSI/STEM Coach, watching how she does her approach has given me the confidence to let go of control, not 100% but I can't do that yet, but let go and just stand back and just watch and I now better understand the value of that. (Post-Interview AL, May 24, 2023)

As the PL sessions continued the teachers began to build confidence in the process of student-directed learning and the transdisciplinary approach. Some of them questioned the PSI/STEM Coach on how lessons could be extended, or how they might adapt their practices, or change the delivery for topics to include cross-curricular connections.

> I have changed the way I think now when planning. I used to think of science, follow the science, and what definition or what theory do I need the students to learn. Now I am thinking about what else is involved in this concept. What is the end result of knowledge? What else can students learn while learning science? (Interview, AK May 19, 2023)

It was apparent to the PSI/STEM Coach that the teachers' planning and purpose for their lessons and the outcomes for their students from the lessons were being questioned. The PSI/STEM Coach recognized that this could lead to their practices shifting to become more transdisciplinary, or at the very least more cross-curricular (interdisciplinary or multidisciplinary).

Increased Student Motivation and Problem-Solving

As the *Grade 1-8 Science and Technology* curriculum (Ontario Ministry of Education, 2022) encourages teachers to prepare the students for their future opportunities, the PL sessions promoted student-directed problem-solving. The PSI/STEM Coach modeled group and individual conferencing and questioning. When students had questions or were stuck, the PSI/STEM Coach would use techniques such as questioning back or have students explain their thinking, thus allowing for students to hear their own thinking and come to the realization of how they could fix, change, or modify the design of prototypes and the coding.

The teachers shadowed the PSI/STEM Coach and heard their students having these conversations during the student-directed activities in PL Sessions 3 and 4. Then the PSI/STEM Coach stepped back and supported the teachers as they attempted similar strategies with their students.

> At first, when students come to me for answers, I would usually just give them the answer. It seemed less work, but then you have students constantly coming to you for answers. So, listening to the PSI/STEM Coach and seeing how she would allow time for the students to struggle and get to their own conclusion, I noticed that work. (Post-session Interview, TK June 1, 2023)
>
> Rather than students coming to me for all the answers, the easy way out of thinking. I would see the coach go up to groups and ask them questions like: What does this do? Why did you put that there? How did you figure out that angle? Explain to me what you are struggling with. And so, I started asking those questions. This made me less of telling them what to do and more of holding them accountable for what they were doing. (Interview, CW May 19, 2023)

From here, teachers commented on the experience of their students engaging and being motivated by the topics of the learning activities. The PSI/STEM Coach involved students in the decisions of what their projects would be focused on and how they would be applied to real-world applications through a scenario. The students were enthusiastic to try and make something "real." The PSI/STEM Coach reflected that teachers need practice creating groupings where they know students will be supported and collaborate.

Need for More Coaching Time

Based on the perceived positive teacher-coach relationships, teachers expressed the importance of the coaching and co-teaching model to build their confidence with facilitating STEM-L sessions. One common comment from the coached teachers was that they wished for more time with the coach. When asked if they would work with the coach again by the PSI's

Supervisor, all replied “yes.” The following quote encapsulates this sentiment, “We could all use more PSI/STEM Coach time” (Post-session Interview, AK May 24, 2023).

Teachers specifically asked for more job-embedded PL, in-class coaching time to observe techniques, shadowing the coach during conferencing with students, and to learn new skills such as coding. There were five PL sessions scheduled but all teachers commented that a sixth session for the PSI/STEM Coach to see the final outcomes from the students’ work would have been beneficial, “...they keep asking when she can come back? She is a very busy person. She was not able to come in and see their final presentation, but I recorded them all. I sent them to her” (Post-session Interview, AM June 8, 2023).

Teachers also believed that they needed more time to debrief and plan the next steps for future transdisciplinary opportunities for their students or next year's classes. They wanted to do this without direct in-class coach support, “We tried debriefing during the last in-class session, but teachers expressed we needed extra uninterrupted time to debrief and discuss more about assessment, next steps, and ideas for next year that they could try” (Fieldnote, May 24, 2023).

The teachers were already thinking of their long-range plans for the next school year and were asking to book sessions or planning time with the PSI/STEM Coach so they could keep working with this method for one or two of their projects. In general, most of the teachers were not intending to convert all of their teaching over, but to have a beneficial mix of approaches and opportunities for students to demonstrate their knowledge and learn in different ways. The PSI/STEM Coach reflected on the realization that having teachers want to incorporate this into their next year's plans was a positive change in their instructional practices.

Learning Coding Alongside Students

Just as the sessions were student-directed and allowed for students to problem solve and discover answers on their own, this was also how the teachers were guided by the PSI/STEM Coach with regards to enhancing their understanding of coding. All teachers involved in this project were at different self-evaluated levels of coding. Based on their responses on the pre-session questionnaire, four teachers felt they were beginners with coding, one evaluated themself as intermediate, and one teacher felt comfortable with coding, but recognized there is always more to learn.

During the PL sessions, coding was included in each session but there were different coding aspects to each session. The coding programs differed in name from the *Scratch* coding program, but all coding programs used were block coding. Teachers felt that it was helpful to watch how the students were introduced by the PSI/STEM Coach to the coding program with a short tour through its features and functions. Then students were encouraged to get into the coding program and try out the coding blocks to get their robots to move or react. The PSI/STEM Coach promoted trial and error learning, with the PSI/STEM Coach there to troubleshoot with the students if necessary. Teachers learned to code as the students were learning by being encouraged by the PSI/STEM Coach to sit with students and interact with the coding program. They were supported to get the robot to do simple things like “move forward” and then to pose the question, “How far do we want it to move forward? Change the block to move forward XX millimeters.”

> It was easier to learn the coding language when sitting down with the robot and trying to get it to do actions. I said to my students I am learning this too, and with the coach’s support I felt that I did not have to have all the answers, because as the coach said in coding you cannot memorize all the code you have to try it out, and there are different ways to code something to do something, so there is not always one right way. This helped me to learn as my students learned. Lots of questions and trying it out. (Post-session Interview, AK May 24, 2023).
>
> I know coding and have coded before, but I had not coded these robots. So I spent some time with my students watching them code and then I got it, it was similar to the block coding I know and so now I would be able to introduce these to my next class, as I feel comfortable coding these too. (Post-session Interview CW, May 25, 2023)

These examples illustrate that meeting teachers where they are at and then helping them feel comfortable with the technology promotes its use for future projects within their classes. For the teachers, some instructional practices they may not have tried before for fear of not being the content knowledge expert, changed to trying it and letting the students know they are not the expert because there is always more to learn.

Cross-Curricular, Dynamic Assessment

One of the concerns the teachers expressed during Session 1 planning was how does a teacher assess something that does not include a quiz or end-of-unit test? Teachers also thought that cross-curricular expectations were overwhelming for the students, and teachers questioned if subjects covered in this STEM-L project would cover enough of the learning goals for those subjects, “I had single-subject rubrics with four levels. I now have multiple subject rubrics, and anecdotal notes, and I can see how students can reinforce concepts from other subjects while doing something that is applicable" (Interview AP, May 26, 2023).

As the sessions progressed, teachers followed the coach and made notes about student learning from conferencing with individuals and groups of students. Teachers were realizing students were able to share more knowledge and learning than they might have with a traditional paper/pencil test by explaining, demonstrating and showing them what they were working on, how it worked and why.

> AM really likes how she can walk around to the groups and ask students to provide her with real-time feedback or explanations about what they are trying to do. She is seeing real-time problem-solving and capturing it on video when students explain how things are working and what they still want to have to happen but haven't gotten to yet. AM expresses how she is seeing stages of growth and learning, much better than an end-of-unit test where students might not be able to answer questions as well as they can show and demonstrate to her right now. (Fieldnote, May 25, 2023)

Due to the engagement level of all students, teachers made comments that they witnessed students succeeding who normally struggled to understand concepts.

> Several times AL has mentioned that she is surprised at this one group and how well they have managed to navigate this task. She is seeing group members completing tasks and asking their friends to let them try things with the robots. AL says that usually this group struggles and needs handholding, but not with this project. (Fieldnote, May 16, 2023)

Assessment rubrics were co-created and shared as teachers were collaborating with the PSI/STEM Coach and also with each other. As the teachers shared their rubrics, the PSI/STEM Coach reflected that there was still work to be done with the teachers with regard to assessment options, however, the student learning and the students' ability to discuss with classroom visitors (e.g., Principal, Resource Teacher) exemplified how concepts and goals were being covered, "I really like how we could create that rubric with the various subjects and cover more for marking in that project. It saved me time and let me let the students have more time working on the STEM-L project" (Interview TK, March 29, 2023).

Changes to Teachers' Beliefs

This second section includes these four sub-themes: Varied Conceptions of Teaching Language and Literacy in STEM; Initial Apprehensions Shifted to Realizations; Reservations

About Accountability Related to Transdisciplinary Learning; Transdisciplinary Learning Impact on Students.

Varied Conceptions of Teaching Language and Literacy in STEM

There were different perspectives identified by the PSI/STEM Coach regarding what integration of language and literacy meant to the teachers. Where the PSI/STEM Coach was describing opportunities to take any story and look for the STEM in the story, the teachers were instead referring to a chapter in a science textbook defining specific terms related to the Science strand focus. The teachers expressed that literacy was being taught during science if students were reading or researching the answer to a question or simply reading questions on a worksheet. One of the teachers (TK) spoke of how she asked students to look up a rock and create a slide talking about what type of rock (e.g., igneous, metamorphic, sedimentary) it was; she referred to this as literacy. Another teacher (AL) spoke of providing students with a slide show for an introduction to a topic in Science and then having them complete worksheets, “My students are expected to read in science class, I assign them questions and they need to answer them using the information from the text or handout I give them” (Fieldnote, March 4, 2023). Their view expanded to include non-science stories, fiction and non-fiction texts. This changed for some of the teachers such as CW:

> Before I think I just thought about literacy as language instruction. When I teach science I would have questions students read and maybe a part from a textbook to read but now I see it can be more that I can use news articles, legend stories and like you did I can look at stories and see how the stories apply to the science. I feel now that there is more I can do to take advantage of this. (Interview CW, May 19, 2023)

When the PSI/STEM Coach provided the students with stories which did not specifically focus on science/STEM concepts but rather asked students to think about what science or STEM they saw within the stories, the teachers began to express how they could see the science/STEM is in these stories, “I think the impact will be having student's awareness of the STEM heightened and seeing the application of STEM and its importance” (Interview CW, May 19, 2023).

The significance here was that students and teachers were witnessing and observing STEM when it is not explicitly labeled, and they were making connections to real-world situations and applications. One example of this was when reading, *The Lion, the Witch and the Wardrobe* by C.S. Lewis there was discussion regarding the STEM of the structures (the bomb shelters and the wardrobe) in the book. Another example in a different classroom featured an accessibility park project, and the PSI/STEM Coach found an article that was coincidentally published in a Burlington, ON paper regarding a playpark with a wheelchair-accessible swing. The PSI/STEM Coach forwarded this article to one of the teachers, who shared it with her class and then they had a follow-up discussion about the engineering design behind the swing. This class had just created their own accessibility park equipment. “So there’s been some things in the news that we’ve also been able to bring in, like there was an article the PSI/STEM Coach sent to me actually last week about a park in Burlington that just installed their first ever wheelchair accessible swing and that was current” (Post- session Interview AM, June 8, 2023).

Teachers also saw the value in using the language skills such as oral presentations, media literacy, reading and writing within the context of the students’ STEM presentations and providing students with multimodal ways to deliver their knowledge. “We had always marked presentations and slides for spelling but now I see I could create reporting within my literacy class and what they report on would be their science knowledge” (Fieldnote, March 30, 2023). The teachers came to realize that there was more than one way to incorporate literacy into the STEM lessons through awareness of STEM in all contexts and through the use of those practiced skills for real-world applications such as presentations.

Initial Apprehensions Shifted to Realizations

When coding was introduced into the *Grade 1-8 Mathematics Curriculum* (Ontario Ministry of Education, 2020), most teachers had never taught coding or even knew what coding was. Then in 2022, the *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022) introduced an expectation in Strand A for teachers to have students code to demonstrate scientific knowledge. Prior to 2022, the PSI/STEM Coach had run optional professional development after school workshops and been visiting teacher classrooms to help introduce coding to both the students and the teachers. Many teachers were still hesitant to code outside of this coaching during their regular class time, so consequently, students might have only received one or two coding periods a term. In many cases the teachers confided in the STEM coach that they were avoiding teaching coding because they did not want the students to see them struggle. The PSI/STEM Coach noted that teachers tended to stick to what they knew and their previous practices, as limiting as this may be, and that is all the students would get to experience.

Through this project and her work in general, the PSI/STEM Coach attempted to change the teachers' cautious nature by allowing teachers to discover, just like the students, that they can code. The PSI/STEM Coach continued to offer coding choices for teachers to demonstrate their knowledge to students outside of the in-class coach time, "...you know, the PSI/STEM Coach just makes it so easy. Let's do this, like she is very easygoing with the kids and with me, and I am actually starting to enjoy working with the technology more" (Post-session Interview TK, June 1, 2023). Another teacher, AL, added:

> I've grown so much in the coding and digital kind of area. But I need more and it's shown me how that is possible and I am very excited about the curriculum. I would love to call the PSI/STEM Coach some more to help me in different areas as this is such a positive experience for the students as well as myself. (Post-session Interview, AL May 24, 2023)

The updated engineering design process expectations in the *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022) were also new to the teachers. Understanding how to approach teaching the engineering design process was limited to teachers believing that this process was similar to the scientific method or experimentation: you give students a topic or have them select a topic related to the strand expectation, and then they simply research it, "In discussion with AL there is the acknowledgement of the steps of the process and appeal for how to approach this" (Fieldnote, May 15, 2023). The PSI/STEM Coach recognized that the teachers needed to have an example of how to approach and conduct an authentic engineering design process activity with their students. This is where teaching transdisciplinary complements this process as both work with real-world applications and solving problems through design, prototyping and group collaboration to make a difference, "Engineering design process cannot be only science, it involves other subject disciplines, I see that now" (Post-session Interview AP, June 5, 2023). From here, this prompted teachers to have discussions with the PSI/STEM Coach on what future projects they could try using a transdisciplinary approach.

Reservations About Accountability Related to Transdisciplinary Learning

During the PL session discussions, teachers made mention of trying to facilitate cross-curricular projects in their classrooms. They came to recognize the cross-curricular skills that could be featured in projects such as how numerical data collection and analyses in a science project requires mathematics skills.

> At first, I was a bit apprehensive about it but after discussing the theme and seeing the session plans, then modifying as we went to suit the needs of the students it was well worth the risk of trying. I covered more curriculum more thoroughly with this method of cross-curricular theme-based [learning]. I think you called it transdisciplinary rather than teaching one curriculum goal per subject and only during that subject. (Interview CW, May 19, 2023)

This process of shifting the teachers' beliefs related to accountability in transdisciplinary learning was done collaboratively, with the PSI/STEM Coach helping guide the teachers into acknowledging what the assessment could look like. Anecdotal notes, conferencing with students and rubrics were the preferred choices of the teachers. The challenge that the PSI/STEM Coach noted was to help the teachers create multi-subject rubrics that would address a number of curricular expectations. To do this, the Grade 1-8 Mathematics, Language and Science and Technology curriculum guides (Ontario Ministry of Education 2020, 2022, 2023) were referred to. Teachers did see that learning skills and curriculum expectations were being met within the project, even though they had not initially set out to assess them, "Flexibility is necessary for teachers to create an assessment plan in their mind as they see the process unfold" (Fieldnote, May 16, 2023). With PSI/STEM Coach's support, teachers slowly began to extend from a single-subject assessment mindset to a multi-subject flexible assessment plan.

> I usually assess by learning goals specific to the subject that I am teaching in that period. The rubric would address that. But now I am seeing how to teach using a real-world problem where there are a number of learning goals from different subjects and also including a bit more emphasis on the learning skills: collaboration, communication and so on. I am including in my notes and my rubric is multi-subject. (Interview TK, March 29, 2023).

The teachers were very motivated at the beginning of the project to ensure that they were gathering marks for their students' achievement in the report card template. Interestingly, the PSI/STEM Coach reflected that she heard this in the comments from their students as well. Part of the purpose of the transdisciplinary approach is to meet the learning needs of students in preparing them for future experiences. This position was something that the PSI/STEM Coach knew that teachers needed to work on in the classroom. The PSI/STEM Coach knew that she needed to elicit a classroom ethos that would embrace the enjoyment of STEM learning over the drive to achieve a mark. With a transdisciplinary approach, accountability was clearly observed by the teachers as they began making daily anecdotal notes and conferencing with their students. The teachers began to gather marks through a different process and method rather than a single test at the end of the unit.

Transdisciplinary Learning Impact on Students

Transdisciplinary learning refers to an approach that integrates knowledge, skills, and perspectives from multiple disciplines to address real-world problems and challenges (Back et al., 2016; Cianca, 2019; Sunarti et al., 2020). When combined with the guidance of the PSI/STEM Coach, students were seen engaged in the experience of STEM-L learning. The teachers also expressed that they benefited from working in collaboration with the PSI/STEM Coach and seeing how and what their students could learn:

> Because I am learning alongside them, I think our relationship is a bit different. Students are seeing me as a learner too and that I am modeling how to ask the STEM coach questions, how to problem solve. So they feel better trying that. (Post-session Interview TK, June 1, 2023)
>
> I think student outcomes were better overall, as they felt comfortable with the STEM coach and I saw them begin to switch from asking for answers to trying to problem solve on their own and wanting to share what successes they were having. (Post-session Interview AM, June 8, 2023)

Teacher participants observed that the students began to see connections between different curricular subjects and to understand how they could make an impact on a real-world situation. The PSI/STEM Coach was there to encourage students and fill in gaps that connected the various disciplines/subjects. Students worked collaboratively with the PSI/STEM Coach who encouraged effective communication and literacy skills. The PSI/STEM Coach reflected that the transdisciplinary learning approaches that were modeled were also able to accommodate diverse student learning styles and abilities; students were able to engage with the topics and in their groups in a way that suited their learning needs.

> I saw students trying new things. I saw groups fully engaged and working collaboratively to try out different parts of the project. I saw students finding how they could contribute and I saw students sharing knowledge as they figured stuff out. (Interview AP, May 26, 2023)

Teachers "seemed surprised at how well their students were working together with the transdisciplinary learning" (Fieldnote, May 25, 2023). The PSI/STEM Coach reflected that the students loved this way of learning and they were asking when the PSI/STEM Coach would be back and if they could do more activities and sessions where they were learning "like this." The PSI/STEM Coach interpreted this to mean that the students enjoyed focusing on solving a real-world problem and trying to solve it, even if it was theoretical or futuristic with a prototype. This type of endorsement led to strengthening the teachers' beliefs that this method is valuable and should be used throughout their planning, in balance with other teaching approaches.

PSI/STEM Coaching Practices

This third section includes the four sub-themes: Good Working Relationship; Coach Is Flexible and Open; Listening to and Meeting Teachers Where They Are; Gradual Release of Responsibility: Extending to the Next Level.

Good Working Relationship

Establishing a good relationship with teachers is critical to working effectively as a coach. In this project, the PSI/STEM Coach had previously worked with three of the teachers, in their classrooms, and during small, one-day coding sessions. The other three teachers knew of the PSI/STEM Coach but had not had the coach working with them in their classroom or done any prior planning with the coach. They were familiar with the coach's work through word of mouth of other teachers. One of these teachers stated, "I feel my interaction with the PSI/STEM Coach was very important and the way we would contribute to each other by sharing knowledge with the students we were modeling collaboration and teamwork together" (Post-session Interview AP, June 5, 2023).

The positive relationships between each of the teachers and the PSI/STEM Coach meant that there was a level of trust achieved between the two parties and the teachers were accepting to have another educator such as the coach in their classroom working with them, "She knows I like to do fun things. She knows that I like inquiry" (Post-session Interview AM, June 8, 2023). This teacher expressed that the PSI/STEM Coach knows her and that this is a good fit for working together. The sentiments between the teacher and the coach were mutual and genuine which encouraged the collaboration to continue.

The teachers expressed that having the coach in their room was a benefit for both themselves (learning professionally) and their students' learning experience. They felt empowered as they were learning alongside their students:

> I would consider her [the PSI/STEM Coach] a great resource because she's made me feel comfortable enough to think that I could, I feel more comfortable in putting digital technology into lesson plans, I would still reach out to her [the PSI/STEM Coach] and ask her for her recommendations. (Post-session Interview AL May 24, 2023)

Teachers expressed that they felt more confident in approaching the coding and technology aspects of their future lessons when the PSI/STEM Coach might not be in the room, because they knew from experience that the PSI/STEM Coach was just an email away. To them, this meant that if there was any troubleshooting that was needed when they were teaching coding and technology lessons, they had the support they needed. This reassurance contributed to an established relationship of trust and respect. The teachers held the notion that the PSI/STEM Coach was not just in and out once or twice, but a constant presence for the teachers to rely on.

Coach Is Flexible and Open

The PSI/STEM Coach's role is to build relationships with both the teacher and the students. The PSI/STEM Coach reflected that it is essential to be flexible and open to what is happening in the school, and in the classroom, and recognize that sometimes the sessions needed to be re-planned or adapted to fit what was going on around them. This quality was recognized by the teachers, "She (PSI/STEM Coach) is much more patient than I can be some days, she gives a different perspective, and is a great person to throw ideas off of, bounce ideas back and forth" (Post-session Interview AK, May 24, 2023). These types of interactions demonstrate the value that the teacher ascribes to the coaching partnership, and that they believe that the PSI/STEM Coach is there to support them and not take over their class or instruction.

The PSI/STEM Coach knew that she could not go into each teachers' booked sessions with the expectation that the plan was set, as there needs to be communication in advance with the teacher and the students. This was necessary so that the PSI/STEM Coach could easily pivot during the session to be responsive to what was happening. Even if only one of the goals for the session was met, this was promoted by the coach as a positive and something the teacher could continue to implement later in the day or week, until the coach was in the classroom again. This promoted the teacher to try things on their own and report back to the PSI/STEM Coach at the next visit.

The PSI/STEM Coach's flexibility and open-mindedness served as modeled behaviour for the teachers. In these circumstances, the teacher could reconsider how sometimes they needed to not worry about getting everything done in a given lesson and allow student learning to happen at its pace.

Listening to and Meeting Teachers Where They Are

The PSI/STEM Coach recognized that it was important to not begin to work with teachers based on the coaches' own agenda, "Teachers do not want to be told what to do or that what they are doing is wrong and how to fix it, they want to feel valued and a part of the process" (Fieldnote, May 24, 2023). The PSI/STEM Coach acknowledged that it was understandable that this method would be sometimes met with resistance and negativity by some teachers. It was therefore extremely important that the coach approached the teachers as collaborators.

> The coach is very open and welcoming to collaboration. She meets you where you are at, and you have a voice. I have listened to other coaches who make you feel uncomfortable, so you do not want to speak up or contribute. With this coach I totally felt we were a team. (Post-session Interview CW, May 25, 2023)

During PL Session 1 planning the coach listened to each teacher, asked questions about what they would like to achieve, discussed how the teacher felt the students were learning and co-created the next sessions, with the flexibility to change any part should the teacher feel that the session was not working for all students. For each subsequent session thereafter, the teacher and coach would debrief during and at the end of the session to make sure that the coach was on the same page as the teacher thinking about how things went and where they should go next. "I feel my interaction with the PSI/STEM Coach was very important and the way we would contribute to each other's knowledge, then share that with the students" (Post-session Interview AP, June 5, 2023).

The coach encouraged the teachers to try approaches on their own or continue the work being done in the sessions in between the times that the coach was present. At first, some were hesitant, but the draw of the transdisciplinary engineering design project, and the students' enthusiasm to engage, influenced the teachers to persevere and report back.

> I feel that following the PSI/STEM Coach around and then branching out on my own, she modeled, and I followed. I felt more confident as I went around and helped students with coding questions and prototype design when the PSI/STEM Coach was not there. (Interview CW, May 19, 2023)

> The coach also made it very clear that she was just an email away. This provided a safety net feeling. AL said she would definitely email me (PSI/STEM Coach) when or if she needed some help, but she felt good to try some coding with her students on her own because she knows I am available to help her via email. (Fieldnote, May 18, 2023)

Being responsive to the teachers in a timely fashion was an integral practice of the PSI/STEM Coach. As such, the PSI/STEM Coach would answer teachers' emails within the working day that they arrived, usually within the hour. This also built-up trust and confidence in the coach as a support for the teacher. The teachers recognized the efforts of the PSI/STEM Coach to be available to support them, understanding the PSI/STEM Coach was working elsewhere but appreciated that the PSI/STEM Coach would get back to them as soon as possible, so they were not waiting too long.

Gradual Release of Responsibility: Extending to the Next Level

For any coaching experience to be perceived as successful, the teacher should be expressing interest in continuing to work with the coach and working to instill new or adapted methods into their practices. In reference to the new *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022) one teacher said:

> It is significantly more challenging for the students, so figuring out how best to approach that, wrapping my own head around it as well, you know, for example, the stem piece, with all the engineering and the coding, they're wanting in both math and science, that's new to me. It was really nice to see her [PSI/STEM Coach] approach to it and how we could get the kids to buy into it, hit those expectations in a way that's fun. More importantly, hands-on, and in a way that is approachable for me. I was really unsure how it's gonna best tackle those things and the PSI/STEM Coach made that very accessible to me. (Post-session Interview CW, May 25, 2023)

With this confidence and the ongoing modeling, the teachers felt they could try out new instructional ideas that they had too. The constant presence of the coaching, the ability to help the teacher understand, the pace and the method of collaboration, all contributed to this perceived professional learning success.

> I really appreciated the interaction with the PSI/STEM Coach and listening to the way she would question students and challenge students with their thinking. She would ask questions about things we know the answer to but ask in a way that the students would feel they really needed to explain. This provided me with seeing how different students

> think and I saw how she could draw information out of the student that I might have discounted if they couldn't write it on a test or assessment piece. (Interview TK, March 29, 2023)

The natural progression of coaching collaboration should begin with the introduction of possibilities, an openness to help the teacher with new or adapted instructional skills, meeting the teacher where they are at, demonstrating and co-teaching for the benefit of the students, and then encouraging the teacher to invite the coach back to showcase what they can now do. One of the teacher participants remarked, "I have ideas now for next year, how I can extend this project. I will be calling the PSI/STEM Coach for support, but I feel I can get started on my own too" (Post-session Interview AM, June 8, 2023). This demonstrated that the teacher had built their confidence while experiencing growth, and the teacher was ready to continue to learn together with the coach; ultimately, the students are the benefactors.

Chapter Summary

Overall, as teachers moved through the PL process with the PSI/STEM Coach, there was a gradual shift in their instructional practices and beliefs. Teachers acknowledged that this was occurring as a function of their relationships with the coach and the methods of coaching they were receiving.

When it came to the teachers' instructional practices, at the beginning of the project, teachers were teaching in a structured manner, however, over the course of the coaching sessions, the PSI/STEM Coach documented that teachers' practices shifted to be more open-ended. Teachers began to verbalize how surprised they were at how simple it was to incorporate a real-world theme into a task and have students working in cross-curricular ways. Teachers also saw the benefit to the students and for themselves from facilitating lessons rather than needing to direct lessons step-by-step. By providing students with the freedom to lead their own inquiry, teachers began to witness students expressing a deeper understanding for the purpose of their work and the students were more invested in producing work. Teachers acknowledged that this motivation was experienced by mostly all of their students, including their students who were typically not fully engaged during group learning tasks and projects. Teachers highlighted how observing the PSI/STEM Coach approach the lessons, interact with the students, and the questioning methods used to draw out student information, was extremely beneficial to their own learning, growth and confidence. Teachers did express concern that the coaching time was too short and would have liked more time or a second go to try the methods again, with the

PSI/STEM Coach there as a support to the teacher. This was evident in the extension of instructional skills with regards to the added coding component in the curriculum, as teachers expressed their hesitance to do coding on their own with their class, as they perceived that they would not be the expert in the room. However, with PSI/STEM Coaching support, teachers' practices changed to letting the students know they were learning alongside them and they would improve their coding abilities together, in partnership rather than the teacher as the expert. Teachers did voice concern that experimenting with the sessions was a risk because they needed to assess certain Science strands and meet expectations for reporting. However, with the PSI/STEM Coach providing cross-curricular rubric samples, teachers recognized that they could assess for more than one subject at a time, and have students understand that they would be assessed in multiple curricular areas. Also, due to the nature of the tasks being student-directed, teachers' strategies of using end of unit tests changed as they now conferenced with their students to garner evidence of student learning and they witnessed students who normally struggled with traditional testing/assessment methods succeed.

CHAPTER FIVE: SUMMARY, DISCUSSION, AND IMPLICATIONS

This chapter will serve as the culmination of this thesis, providing an interpretation of the research findings from the PSI/STEM Coaching sessions with teachers. It will also present the implications of the research findings and provide potential future directions for this topic. Chapter Five will begin with a summary of the study and then there will be a discussion of each of the three major thematic findings in the context of literature. This chapter will conclude with implications for practice, theory and future research, and finally, limitations.

Summary of the Study

STEM (Science, Technology, Engineering, and Mathematics) education has the potential to bring a shift to the classroom culture and curriculum (Margot & Kettler, 2019). The goal of STEM education is to prepare students to meet the challenges of our rapidly changing world (Ontario Ministry of Education, 2022). Relevant to the present study is the reality that teachers need to be prepared to present students with real-world applications so that they see the practical value in what they are learning (Cianca, 2019). Many teachers need professional learning support to ensure that they are effectively presenting the curriculum in a way that the students are benefiting most from it (Shernoff et al., 2017; Siegel & Giamellaro, 2021). Accordingly, this prompted the current study's research question: After participation in a professional development coaching model from transdisciplinary approaches for teaching STEM-Language Literacy education, how do Grade 4-8 teachers' instructional practices and beliefs change?

The findings of this study have provided some insights into understanding six Grade 4-8 teachers' instructional practices and beliefs as a function of transdisciplinary coaching in STEM-Language Literacy education. During this study the PSI/STEM Coach met with each of the teachers on five occasions: the first session was a planning session, with the subsequent sessions as in-class, interactive coaching sessions related to the new *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022) expectations including coding and engineering design and the *Grade 1-8 Mathematics Curriculum* (Ontario Ministry of Education, 2020) coding expectations. The language and literacy component of STEM-Language Literacy coaching focused on encouraging teachers to use any story, not specifically STEM-content labeled, to engage students in identifying with STEM concepts in everyday situations; implicitly, this communicated that STEM is all around us.

The PSI/STEM Coach adopted a transdisciplinary approach and re-introduced teachers to the concept of cross-curricular teaching with Mathematics, Science, Techology and Language and Literacy. This began with identifying real-world situations and challenges, and then guided the teachers to use student-directed STEM-Language Literacy inquiry where the teacher's role was that of a facilitator. Over the course of the sessions, assessment was discussed as accountability through reporting was predominant on the teachers' minds with respect to how to generate marks from such open and flexible learning scenarios. This was addressed via multi-subject/cross-curricular rubrics that included expectations from various subject curricula. This encouraged class time to be imbued as a project-based learning, inquiry-mode environment, and less traditional and subject-specific structure. Through participation in this PL coaching model, teachers began to integrate STEM subjects with language literacy more effectively. In the future, they might design lessons and projects that connect concepts from multiple disciplines, promoting a more holistic learning experience leading to improving student understanding and outcomes.

Discussion

The following discussion of the findings is separated in accordance with the three sections in Chapter 4: Changes to Teachers' Instructional Practices; Changes to Teachers' Beliefs About STEM; and PSI/STEM Coaching Practices. All of the respective sub-themes from these three sections are included in this discussion.

Changes to Teacher Instructional Practices

The following provides an elaboration on the changes to teachers' instructional practices.

Started With Structured Practices

The teacher participants in this study started with very structured practices. For example, they had organized time schedules on the boards in the classroom labeling which period of the day was for which subject discipline, and they had teacher-directed ways that they introduced a new strand in science. Indeed, it has been documented that time to implement rich STEM activities in a classroom is restricted by school bell schedules (Shernoff et al., 2017). In the classrooms of the teacher participants in this current study, there were often teacher-directed introductions to a Science strand with definitions, followed by a worksheet or two and then a quiz to check for understanding. This is commonly referred to as traditional teaching, in which there is a teacher-directed structured approach where students are taught in a manner while passively sitting and listening (Tularam & Machisella, 2018). This traditional teaching, which can include rote learning, still is taking place even though education researchers believe rote learning is outdated and that the memorization of facts actually inhibits deeper understanding of the concepts (Tularam & Machisella, 2018). The teacher participants in this study also expressed that they typically only teach one subject per period assigned, which was evidenced by the time schedule on their boards. Subject-area silos in education remain a constant in today's schools (Zahradnik, 2018). Silo teaching of subjects might help schools with organization, but they do not contribute positively to impactful student learning (Ramirez, 2013). The real world works in an integrated fashion with multiple disciplines contributing to solutions to real world problems. Helping teachers to shed their structured silo curricular approaches by integrating subjects will help students gain an increased understanding of real-world problems, they will retain what they learn longer, and they will be more motivated to learn (Mathison & Freeman, 1998). Yet, Bryan et al. (2016) suggest that STEM integration must be more than simply teaching disciplines together. They argue that STEM must be rooted on the fundamental ideas of various disciplines (Bryan et al., 2016). This is accomplished by integrating largely through the science, engineering, and mathematical practices, the building toward 21st century skills all with the purpose of solving a real-world problem or task (Bryan et al., 2016).

As teachers become familiar with content and cross-curricular facilitation, they start to demonstrate that they can balance structure with integrating curriculum (Shernoff et al., 2017). An integrated curriculum fosters student learning in a holistic way, without the restrictions of single subject boundaries (Satchwell & Loepp, 2002). The students are learning to transfer their knowledge to other areas, while experiencing mutual reinforcement of concepts (Lopez, 2022; Satchwell & Loepp, 2002). Research on the integrated approach suggests that the brain learns best in multi-path, immersion-style learning in real-world situations (Jensen, 1996). The transdisciplinary approach is integration driven by real-life problems to solve (Cianca, 2019). Through the transdisciplinary approach the teachers in the current study witnessed students' attention being captured by their interests in what they were learning.

Shifted to Inquiry-Based, Student-Directed Learning

There was a shift in teachers' practices as they worked with their students and the PSI/STEM Coach. The sessions were set up to be cross-curricular and transdisciplinary. The emphasis was on student-directed learning where students were asking questions, conferencing with the PSI/STEM Coach and their teacher, and ultimately leading their own learning. In other studies (e.g., Attard et al., 2021) teachers have witnessed the positive outcomes of providing an environment for students to lead their learning. This learning environment did not center on single subject disciplines, but transdisciplinary approaches that gave students a real-world application to solve using STEM knowledge with literacy as a prompter. As teachers relaxed into the role of facilitator, they recognized how effective true inquiry-based learning could be for all students (Attard et al., 2021).

A shift in teaching practices from traditional methods to more inquiry-based and student-directed learning involves teachers taking on the role of facilitator rather than being the sole source of information (Keller et al., 2018). Students are encouraged to ask questions, investigate topics of interest, and work collaboratively to find answers. This shift impacts teaching practices by promoting active learning, critical thinking, problem solving, ownership, collaborative learning, and technology integration. The teacher's role is to encourage, provide a supportive environment, and to act as guides of discussion (Keller et al., 2018). During the coaching sessions, the teachers observed the PSI/STEM Coach help students formulate meaningful questions, suggest relevant resources, and offer guidance where needed. The teachers began to shift into this model as the coach was providing a supportive learning environment for all. The teachers saw that allowing students the freedom to explore and learn independently was as important as the more structured practices they were providing on the daily basis. It is essential to strike a balance between traditional teaching approaches and engaging in inquiry-based learning (de Jong et al., 2023). The skills students were developing such as research, analysis, communication, and critical thinking are valuable and will be applied throughout their lives (Wale & Bishaw, 2020).

Increased Student Motivation and Problem-Solving

During the coaching Sessions 3-5, students were engaged in inquiry projects with their small groups. The teacher participants made comments to the PSI/STEM Coach about how this was the first time they had experienced all of their students being engaged and motivated. The teachers attributed this student motivation to a few factors that they had discussed with the PSI/STEM Coach during their sessions. They believed that one factor was that the transdisciplinary STEM task had students working to solve a real-world problem. Working on real-world problems within the STEM disciplines makes learning more relevant to students and teachers (Takeuchi et al., 2020). The students were making the decisions of what their group project would be responsible for and negotiated within their group and through conferencing with the PSI/STEM Coach. The teachers observed the hands-on learning that allowed students to apply theory to practice. This hands-on learning method of teaching and learning encourages students to engage in the process more actively (Freeman et al., 2014). Students in active learning classrooms tend to express more positive attitudes towards the learning (Freeman et al., 2014). This methodology has been supported for almost a century by educational theorists such as John Dewey. Dewey (1938) had a focus on providing meaningful experiences that contribute to students' growth as learners. He believed that this type of pedagogy could help shape a well-rounded student who is able to think critically and transfer tangible skills into the world (Dewey, 1938).

Need for More Coaching Time

All teachers expressed the need for more coaching time with the PSI/STEM Coach. Seemingly, the teachers felt comfortable with this PSI/STEM Coach and there was an established relationship with them, as well as their students with this PSI/STEM Coach. Teachers began to express that they were professionally learning and growing. This may have been attributable to the documented quality of an effective coach as one that is able to work collaboratively with the teachers, supporting their unique needs (Frazier, 2020). Teachers began re-evaluating how they could adapt future lessons; this could be an indication that they were building their confidence in new skills. The teachers knew that with more coaching time they could continue to strengthen their understandings of STEM, try out instructional methods with their students without worrying about things working, and facilitate student-directed practices for all their students. Similar to other educators who have had STEM professional learning (Quigley & Herro, 2016), these teachers knew they needed to be prepared to teach with the technology and have the foundation of STEM to fully implement proper STEM instruction.

In this school board, PSI/STEM coaching needs to continue as the teachers in this study self-identified their level of knowledge within the curriculum and the four disciplines: science, technology, engineering, and mathematics. As many teachers went through their post-secondary education prior to STEM becoming a main focus, many current teachers have little to no practice in STEM approaches (Shernoff et al., 2017). The teachers in the current study self-identified their STEM understanding as beginner or advanced, but not in all four disciplines (subjects). This has an impact on their initial release of structured instructional approaches and teacher-directed learning. To be able to accomplish successful integration, teachers must be comfortable with STEM and practice integration to promote the skills with students (Faikhamta, 2020). Not all teachers have a STEM background, many only acquiring STEM pedagogy during infrequent

PD opportunities (Honey et. al, 2014). Continued STEM coaching is necessary to facilitate student-directed learning and support a transdisciplinary approach.

Learning Coding Alongside Students

The six teacher participants involved in this study were asked to self-identify their level of technology understanding in coding, robotics, and programming. Surveys from various countries have shown that elementary teachers do not feel prepared to teach coding (Ohashi et al., 2018). The teachers in this study self-identified themselves as “not techie” or not knowing much about coding which manifested in the teachers limiting the amount of time their students got to code due to their lack of knowledge and confidence. Teachers felt that if they were not the expert how would they troubleshoot or explain concepts in coding to their students. To ameliorate for this discomfort, teachers would only code with the PSI/STEM Coach in the room. Over the coaching sessions, the teachers found that sitting with their students and coding alongside them, they were problem solving and discovering how to code together. Troubleshooting was a whole class collaboration: once one group knew how to do something they could share to everyone else. The PSI/STEM Coach supported them by meeting the teachers at the level of coding that they understood, even if that was a beginner level and then coaching everyone through the basic concepts. When the teachers saw the PSI/STEM Coach model this practice, it became a role that the teachers could imitate when the PSI/STEM Coach was not in the class. The PSI/STEM Coach repeatedly used affirming statements that reiterated that there is infinite code and many ways to code to get a similar or same result, so the main learning with coding is understanding what the blocks do and then trying them out.

Cross-Curricular, Dynamic Assessment

During Session 1 of the professional learning, assessment was discussed as the teachers were concerned about the fact that they would need to generate marks from the student learning. They were mostly focused on the summative assessment possibilities and what these tasks would look like. *Growing Success* (Ontario Ministry of Education, 2010) provides the definition of assessment as the process of gathering information on how well students meet the learning objectives towards curriculum expectations. The Ontario report card hosts the final evaluation by subject (Ontario Ministry of Education, 2010). Conducted at the end of the learning period to evaluate students’ overall understanding and mastery of the material, the main purpose that the teachers wanted to ensure was that they could assign a grade to each student. For the teacher participants in this study, the most common summative assessment task was a quiz or a test, or a project evaluated with a rubric. These well-known types of assessment fall short of capturing the complexity or breadth of how assessment functions on a daily basis in the classroom (National Academy, 2001). The PSI/STEM Coach noted that the rubrics these teachers were using were single subject rubrics with the expectations or outcomes cut and pasted from the curriculum for each of the Science strands. Over the course of the coaching sessions, teachers and the PSI/STEM Coach discussed the cross-curricular expectations clearly being met by this transdisciplinary project. As established in the literature (e.g., National Academy, 2001) teachers began to see the value in collecting formative data. These teacher participants were interacting with the student groups and asking questions about their projects, working with students to read code, and conferencing with student groups and individuals about their prototypes and discoveries. Teachers still perceived a need to have summative assessment, so with the PSI/STEM Coach they developed flexible cross-curricular rubrics with student input that could be individualized for different learning needs within each class. The rubrics also allowed for the formative assessment to be considered.

Changes to Teachers' Beliefs

The following portion of the discussion elaborates on the changes to teachers' beliefs.

Varied Conceptions of Teaching Literacy in STEM

During coaching Session 2 of this study, the PSI/STEM coach discussed with the teachers how to choose a story to read with their class as a way to introduce language and literacy into a STEM lesson. The PSI/STEM Coach noted that the teachers initially thought that teaching with literacy involved using science specific textbooks, having students read content-related chapters and answer related questions. However, in this study the PSI/STEM Coach suggested teaching with literacy by taking any story or text and having students identify the STEM concepts in the story; these included even stories not specifically labeled as STEM texts.

Stories can be engaging educational tools because students are entertained by them and can easily recall facts from the stories they have read (Moitra, 2014; Rossiter, 2002). The teacher participants in this study witnessed engagement in their students that grew as they started discussing other books or stories they had read and the STEM concepts that they saw embedded in these texts. Teachers saw students experiencing a heightened awareness that STEM is all around them in their daily lives, making the applications real. Another outcome of introducing STEM concepts through stories was that the creative nature of students now could be explored through their coding and STEM problem-solving ideas; they saw that STEM is everywhere. The teacher participants in this study began to see how students were open to working together with the teacher as well.

Initial Apprehensions Shifted to Realizations

The teacher participants were cautious with what they thought they could do in relation to their understanding of STEM disciplines. It has been documented by several researchers (e.g., McPhail 2018; Siegel & Giamellaro, 2021; Zeidler, 2016) that among elementary teachers there is a lack of confidence in their beliefs about their STEM knowledge. Once immersed in the coaching sessions with the PSI/STEM Coach, teachers realized what they knew more about coding, engineering design, and technology than they had given themselves credit for.

The teachers in the current study qualified themselves as beginners with respect to STEM knowledge and they expressed that they were not technologically oriented. Working with the PSI/STEM Coach, teachers began to express an unexpected (on their part) gratification for understanding the STEM concepts, coding and the technology integration and use. It has been found that when teachers work with a coach in a discipline or content-area such as STEM, their practices are improved and their understandings are enhanced (Giamellaro & Siegel, 2018). As well, the teachers in the current study engaged in activities and discussions with the PSI/STEM Coach that supported their confidence in their own abilities. This was continually reconfirmed by the PSI/STEM Coach through positive affirmations. This, in turn, prompted the teachers to try activities outside of their STEM instructional comfort zone, take risks and continuing to grow in the areas of STEM they had initially felt least prepared for. This cycle of trying new approaches, such as the transdisciplinary approach with STEM-L then engaging with a coach by partnering and shadowing, is a common attribute of effective coaching (Knight, 2007). In the end, the teachers in the current study expressed some extent of disbelief in their new abilities but were happy that they were progressing. It may be the case that the PSI/STEM Coach's confidence in the teachers led to the teachers believing in themselves. It was found by Gallagher and Bennett (2017) that coaches' confidence in their own coaching knowledge and abilities does influence the professional learning outcomes for the teachers that they work with.

Reservations About Accountability Related to Transdisciplinary Learning

One of the biggest challenges expressed by the teachers in this current study was their beliefs that they had to get through all of the curriculum in a set amount of time by teaching it through individual subject disciplines or siloes. This belief has been noted by Spielman (2018) who found that teachers have a conception of the curriculum that is of independent domains. Spielman (2018) expressed that curriculum should not be composed of discrete knowledge that has been determined to be required to pass an exam.

Teachers in this current study were cautious about engaging in transdisciplinary learning because they are accountable for reporting on student achievement in discrete subject areas. Any experimentation or change to routine was met with apprehension as they were afraid to waste precious instructional time and did not see how students could learn multiple subject expectations at the same time. The connection between teachers' practices and their beliefs is such that what they believe they are doing or cannot do is not always reflected in what the actually are doing (Borg, 2017). Interestingly, over the course of this study's coaching sessions the teacher participants became very aware that their students were learning more with great depth through the cross-curricular instructional approaches as the transdisciplinary learning promoted real-world applications. It is the case that evidence gleaned from lived experiences and examples of student learning is the most impactful on shifting teachers' reservations and beliefs (Margot & Kettler, 2019).

Transdisciplinary Learning Impact on Students

The teachers in the current study witnessed the transdisciplinary approach integrating knowledge, skills and perspectives from multiple disciplines while addressing a real-world challenge. At first these teachers did not fully understand the scope of transdisciplinary learning, however after working through the coaching sessions, the teachers agreed that student outcomes were positive as they saw value in what they were doing while learning about STEM concepts, principles, and theories. Importantly, they recognized that the transdisciplinary learning approach could accommodate the various learning styles and abilities of the students, leading to greater engagement and collaborative problem solving. Indeed, the transdisciplinary approach in STEM education supports students engaging in collaboration, considering many perspectives, and working toward problem-solving through mutual discovery (Back et al., 2016). Learners retain 75% of what they actively do compared to 5% of what they hear and 10% of what they read (Diamond, 1989). The teachers also needed to collaborate with the PSI/STEM Coach and with each other to consider multiple perspectives and to discover how to teach from a STEM-L perspective. Working with the PSI/STEM Coach elicited comfort and confidence for both the teacher and the students.

PSI/STEM Coaching Practices

Teacher coaching is a process that involves providing personalized support and feedback to educators to enhance their instructional practices and professional growth. Through the five PL coaching sessions in this project, teachers grew in their understanding of how they can easily incorporate any literacy story into their STEM curriculum. The story does not have to be specifically STEM labeled for students to begin to identify STEM concepts all around them and within the story they are reading. Initially, teachers felt that only STEM content specific text was appropriate to use, which does hold its own terminology and subject-specific merit, however opening their minds to recognize the STEM concepts in non-STEM text, and having students make connections to these STEM concepts in non-STEM contexts, was deemed valuable when teachers saw this in practice. Teachers also advanced in their confidence with what they felt they knew or the experience they had with the new *Science and Technology* curriculum (Ontario Ministry of Education, 2022). Initially, they believed they were novice and unprepared to teach certain aspects within the new Science curriculum, however with the PSI/STEM Coach bridging gaps, demonstrating alternative methods, and drawing out the teachers' (and students') prior knowledge, teachers began to make links to their knowledge and began to recognize the skills and abilities they had within themselves. With this change in their beliefs, there was added confidence where teachers were enjoying what they were teaching, rather than being concerned that they were not the expert at everything. One major barrier to receptivity was that of assessment and evaluation which teachers see as accountability for having "covered" the curricular strands and subject matter in the grade. At first, on the part of the teachers, there was hesitation and they questioned whether curricular expectations were going to be covered when using approaches with a transdisciplinary learning style. However, once the PL sessions were in progress, teachers' apprehensions waned and they saw the value of the method, plus the richness of the curriculum content that was being explored. The teachers also shifted their beliefs regarding being the expert in the classroom; this was similar to their shift in practices. The collaboration with the PSI/STEM Coach and with their students produced enhanced student engagement and understanding, providing teachers with a changed mindset that this method could be added to their long-range planning in the future.

Through coaching, teachers can gain a deeper understanding of their own teaching practices, strengths, and areas for improvement. This increased self-awareness can lead to a shift in their beliefs about their teaching strategies. Working with the PSI/STEM Coach, the teachers identified a number of traits which provided for the success of the teacher–coach relationship.

All teachers in this study wanted more coaching time with this specific coach. The relationship between the teacher and the PSI/STEM Coach was unique to the teachers' needs and personality in each case. Overall, the effectiveness of the coaching was likely due to the positive relationship where teachers felt safe to express their needs and where they felt they were collaborating and working as a team with the coach. Through the PSI/STEM Coach listening to the teachers, taking feedback and adapting to the teachers' needs, the teachers saw a flexible and open coach who was there for them, not for an alternative agenda. When the teachers were challenged or expressed a lack of confidence, the PSI/STEM Coach was able to meet the teachers where they were at, where they were comfortable, and together they worked toward reachable professional goals. This welcoming collaborative style was embraced by the teachers allowing them to step outside their comfort zones and extend their practices. With the teachers seeing that they could take risks with the PSI/STEM Coach there to provide support without judgment, the teachers slowly were ready to try some new instructional approaches on their own, this gradual release of responsibility from PSI/STEM Coach to teacher was a small step and still required reinforcement, as the teachers asked for more support in the future to continue to build their confidence with the curriculum.

Good Working Relationship

Coaches need to be skilled communicators and relationship builders who can listen, empathize, and build trusting relationships with teachers (Knight, 2019). When partnering to work with teachers the coach should be seeing themself as an equal collaborator, recognizing that each teacher will bring expertise into the coaching conversation (Knight, 2019). The teachers in this study expressed that their PSI/STEM Coach was able to communicate and build a relationship with them. The relationship with the PSI/STEM Coach was established quickly with the teachers and then on the first visit to the classroom with the students. Building rapport should be a coach's first priority and is crucial to all of their coaching encounters (Collet, 2012). Having a strong relationship with both the teacher and the students was mutually beneficial for all involved. It is crucial that to enhance a teacher's instructional impact that there is a shared understanding between the teacher and coach in their collaborative relationship (Knight, 2019). Teachers need to perceive that there is trust and respect between them and their coach; this is essential to the coach-teacher collaboration (Gallagher & Bennett, 2018). In the current study, the teacher participants described how the PSI/STEM Coach demonstrated these qualities.

Coach Is Flexible and Open

The teachers in the current study expressed that they wanted more time with the PSI/STEM Coach to continue their professional learning, building their own skill sets with confidence, and to have trusting colleagues to work with. Teachers expressed that their communications with the PSI/STEM Coach were open, without judgment, and flexible to their different needs. Coaches who take a partnership approach garnering teacher input are able to provide instruction for the teacher while demonstrating how the practices will be implemented in their class (Knight 2019). While the PSI/STEM Coach was able to help teachers identify a clear picture of their students' reality in the class, the coach followed best practices (Knight, 2019) and did not tell teachers what to do. Openness and flexibility come from the coach sharing ideas, asking questions of the teacher, and listening to the teacher's ideas as well (Bohm, 1996).

Listening to and Meeting Teachers Where They Are

In the current study the teachers had experience with other coaches who would come into their classroom as the expert, not wanting to collaborate with the teacher but to tell the teacher what they needed to be doing and what they were doing wrong. The approach was different with the PSI/STEM Coach, the teachers knew that the PSI/STEM Coach was there to support them at the level that they and their class were at, without making anyone feel uncomfortable regarding their starting knowledge place. A coach should listen to the teacher, engage in supportive dialogue, observe the teacher's interactions with students and then model practices in the classroom (Knight, 2007). Coaching involves acknowledging that the teacher will need to modify their practices to meet the unique needs of their classroom, and a coach can help the teacher recognize their individual strengths (Knight, 2019).

The teacher participants discussed the collaborative nature of the PSI/STEM Coach, how the PSI/STEM Coach listened to what the teacher's expectations were and then started at a point in the curriculum where their knowledge was at, and they were comfortable. The teachers felt they were working as a team to co-teach and were then more open to suggestions from the PSI/STEM Coach rather than being told what or what not to do. Knight (2007) speaks about the importance of the partnership approach in coaching. The partnership approach experienced by the six teachers in this current study included a sentiment of equality in which the coach and teacher were equal partners. There was choice of what and how the teacher wanted to learn and respect for the teacher's voice. Listening to and meeting teachers where they are is premised on an earlier finding: relationship building.

Gradual Release of Responsibility: Extending to the Next Level

Based on the teacher participants' interview responses, it was concluded that the STEM-Language Literacy coaching was perceived to be impactful on their practices. All of the teacher participants expressed interest in working together more with the PSI/STEM Coach; this verifies that they felt comfortable with the PSI/STEM Coach in their teaching space. The PSI/STEM Coach sought to help the teachers build their confidence in the areas addressed by the sessions: literacy, coding, technology, and the engineering design process using a transdisciplinary learning method. The coaching was also specific to each teacher and meeting their needs as well as their students' needs. From here the PSI/STEM Coach saw some movement towards teachers being able to try out the instructional strategies and lessons on their own. The PSI/STEM Coach acknowledges that there is still work to be done with helping teachers understand how to communicate with their students and facilitate STEM learning, but progress was made. This professional learning work is ongoing and needs to be founded on such strong relationships as those built between the teachers and PSI/STEM Coach. Building a positive and trusting relationship between teachers and their coach is integral to continuing the process of collaborative learning (Collet, 2012). It has been found that the teacher will take on a greater role with regards to planning and facilitating lessons, with the coach there to scaffold support as required (Collet, 2012).

Implications for Practice

The findings of this research indicate that there are implications for practice that might be considered. The *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022) includes cross-curricular instruction examples in it. This curriculum also has website support which integrates cross-curricular activity suggestions. Teachers need to familiarize themselves with all components of the new curriculum. Yet, STEM itself is not curriculum; STEM is an approach to learning that allows for four disciplines to be integrated into relevant real-world experiences for students (Vasquez et al., 2013). In some recent studies STEM is now being referred to as STEAM with the Arts incorporated in as one of the disciplines. Much of the literature in STEAM education remains focused on teachers' understanding and/or implementation of integrated STEAM instruction (Jacques et al, 2019; Quigley & Herro, 2016). With coaching support, the practice of many teachers can evolve from single subject teaching to STEM with cross-curricular objectives and connections.

Transdisciplinary integration, the most advanced level of STEM teaching and learning, has been shown to improve students' achievement in higher-level cognitive tasks through the application of STEM disciplines (Caton, 2021; Cianca, 2019; Satchwell & Loepp, 2002). In this study, teachers clearly witnessed students achieving such higher-level cognitive tasks. Throughout the coaching sessions with the transdisciplinary approach, the students of the teachers in this study were applying their knowledge from literacy, science, mathematics, technology, and engineering to solve an authentic problem they negotiated and that was of interest to them. The students' communication and collaboration skills increased, and they were practicing the engineering design process as they proceeded through the sessions.

Teachers should not be expected to adopt transdisciplinary integration within STEM without professional learning support. Recently, the Ontario Ministry of Education has provided some training videos and after school PL sessions. In Ontario, for the 2022-2023 school year there was one mandated PA day dedicated to Skilled Trades and STEM. There is no way to monitor how well teachers participated in the virtually offered PL sessions. PSI/STEM Coaches require more time with teachers to help them bridge the gaps in their practices and beliefs, to help them establish more confidence in their STEM knowledge and to help them expand their thinking to make cross-curricular and transdisciplinary connections. This will, in turn, support the push for more students to pursue the Skilled Trades as STEM plays a big role in these high school courses and careers.

Strengthening teachers' knowledge base and confidence, may contribute to them providing continued transdisciplinary approaches with their students (Vasquez et al., 2013). To assist with this, working with the PSI/STEM Coach, teachers can collaboratively plan authentic STEM-L experiences. For teachers who may not have access to school district provided coaching support, online professional learning communities could be an access point to discuss, collaborate, and plan transdisciplinary teaching units. Another consideration to provide PL support is a team sharing approach. This team sharing might be within one particular school district or through a provincial STEM teachers' organization (e.g., Science Teachers' Association of Ontario [STAO]). Since school districts all have an internally shared virtual platform, a course space could be set up by the STEM consultants/coaches for teachers to have access to where shared resources and lesson plans could be housed. This might be modeled after the provincial organization, Science Educator Leaders of Ontario (SELO) that provides a sharing platform for across district collaboration. On SELO's platform, STEM and science leaders can have access to resources and then share them back to their staff. Virtual sharing of resources and directing teachers to the supports on platforms would benefit all educators as well as their students.

Ontario has released its new *Grade 1-8 Language Curriculum* (Ontario Ministry of Education, 2023). In this curriculum there is a very prominent section that highlights integrating cross-curricular learning from language into all other subjects. Herein, teachers can see the justification for STEM education implementation with language and literacy instruction. STEM-L is the teaching of STEM with integrating texts that are not based specifically covering STEM, information, but to engage students in observing STEM is all around them, in the real-world. As the document states there is importance for engaging diverse perspectives within the STEM subjects and encouraging different ways of thinking (Ontario Ministry of Education, 2023). Future teacher PL needs to explicitly address literacy as an integral aspect of STEM knowledge mobilization.

To fully adopt a transdisciplinary approach, educators need to look at how to step outside of siloed single subject teaching and integrate subjects. The *Grade 1-8 Science and Technology Curriculum* (Ontario Ministry of Education, 2022) has incorporated cross-strand and cross-curricular links into their planning supports online. The Grade 1-8 *Mathematics Curriculum* (Ontario Ministry of Education, 2020) has updated their exemplars, and this curriculum is also suggesting cross-strand and cross-curricular links. There have been a number of recent webinar tutorial sessions provided by the Ontario Ministry of Education. How do we get teachers to familiarize themselves with these new expectations and provide them support through coaching to implement STEM-L education?

Finally, there might be a STEM, STEM-Language Literacy, or STEAM in-service course series designed as additional qualifications courses. In Ontario, there are grade division science and technology, and math courses for in-service elementary teachers and single subject courses for in-service secondary teachers. There is a technology course specialist series, though it does not integrate STEM. There are no engineering courses at this time. Perhaps an official STEM AQ three-part series (working to a STEM specialist) with funding might encourage more teachers to take this and to help upgrade their skills with STEM. More importantly, we need the teacher unions to support teachers and encourage teachers to complete AQ specialists, as it is not currently a requirement to upgrade skills by taking at least one AQ per teaching year.

Implications for Theory

In addition to the implications for practice, this study and its findings have implications for theory. Dewey's theory of pragmatism from 1938 has contemporary applications. People learn through a hands-on approach; through experiences, not just through simple one path (siloed) considerations, students need to learn through questioning about real-world situations (Dewey, 1938). This research study has demonstrated to the teacher participants that students were more engaged and motivated when it came to learning STEM-Language Literacy through a transdisciplinary approach. The teachers acknowledged they could adapt their teaching practices to provide more hands-on, student-directed learning. Teacher beliefs shifted to acknowledge that the transdisciplinary approach encouraged student engagement within all of their students. Teacher self-efficacy increased as these teachers began to realize their own competence (Bandura, 1997) with regards to STEM knowledge and skills, especially coding. Initially, the teachers felt that they needed to be the expert in the room, however as they became comfortable learning the coding alongside their students, they witnessed more of their own abilities which increased their self-efficacy. Through positive coaching interactions and witnessing impact on student learning teacher's self-efficacy increases (Zhou et al., 2023). The teacher participants in this study asked for more PL with the PSI/STEM Coach. This may be interpreted as confirmation that instructional coaches who establish a partnership with their teachers are able to facilitate effective practices (Knight, 2007).

Teaching involves more than just knowing the subject matter, it requires an integration of the content knowledge and the pedagogical knowledge to create meaningful experiences for students (Shulman, 1987). Teachers with strong TCK (transforming content knowledge) can reframe and present content in ways that are more comprehensible to learners (Figg & Jaipal, 2016). Teachers need to have strong PCK (pedagogical content knowledge) to be able to explain complex concepts, anticipate and address misconceptions and provide appropriate instructional materials and strategies (Figg & Jaipal, 2016). Within the current study, the PSI/STEM Coach works toward developing the teacher's confidence in drawing on their PCK and TCK, building their knowledge in these areas by making connections.

Finally, teachers began to see efficacy in the practice changes from single subject, siloed traditional, teacher-directed lessons to exploring the transdisciplinary cross-curricular STEM-L approach where students directed the learning. The teacher participants had the opportunity to be fully involved in the coaching process as an active participant co-constructing their knowledge with the PSI/STEM Coach. At first the teachers observed the PSI/STEM Coach model practices with the knowledge that they were always welcome to co-teach. As their beliefs about STEM teaching shifted, the teachers began to see how the PSI/STEM Coach modeled the lessons and they joined in co-teaching. In this way the teachers were guided in their practice alongside the PSI/STEM coach. These practices align with Vygotsky's social constructivist theory (Vygotsky, 1991) and the gradual release of responsibility (Pearson & Gallagher, 1983) as teachers were scaffolded through the PL experience with the PSI/STEM coach, eventually able to work with their students independent of the coach.

Implications for Future Research

This study's findings have prompted additional questions to consider for future research. Educational researchers might want to engage in work that addresses where prior knowledge in STEM originates from before teachers enter their classrooms. What is the prerequisite learning and how can this be enhanced with efficacious knowledge about teaching STEM? This might begin in preservice education programs by examining if teacher candidates feel fully prepared to teach STEM to any grade and how many hours of STEM-Language Literacy education, they need to feel confident to teach. Teacher candidates who have an undergraduate degree in a science or math discipline often feel more prepared for teaching science or math (Margot & Kettler, 2019), but future research might focus on other teacher candidates who lack such prior knowledge. This research might include a questionnaire asking teacher candidates to self-assess their STEM teaching preparedness including any university courses they took that were STEM focused.

An additional proposed project might be an intervention study in teacher education programs designed to examine the impact of a STEM course that teacher candidates take alongside other teaching methods courses that they take in science, math, and digital technology. The intervention study might investigate the optimal amount of STEM learning needed for teacher candidates to develop basic competencies. Language and literacy education methods would be infused into the STEM course and presented in a transdisciplinary way as a model for how this could be done within the elementary classroom. Finally, a phase of this intervention study might be to follow teacher candidates into their practica and document how many receive mentoring from their associate teachers in STEM teaching and if teacher candidates teach STEM-Language Literacy lessons in their practicum.

In-service teachers are the force responsible for implementing the inquiry-based, cross-curricular, transdisciplinary teaching approaches that the *Ontario Science and Technology* (Ontario Ministry of Education, 2022), *Mathematics* (Ontario Ministry of Education, 2020), and *Language* (Ontario Ministry of Education, 2023) curriculum are all emphasizing. However, a contemporary research study might ask how are these experienced teachers being encouraged to self-reflect on their knowledge and to update their skills and what that should look like? Similar to the process taken with the teacher candidates, this might begin by examining how prepared teachers feel to teach the STEM to any grade. A questionnaire could be administered to ask teachers to self-assess their STEM-Language Literacy teaching, how familiar they are with the transdisciplinary method and how they have prepared to teach the new curricula in science, math and language. An intervention study might be investigated here as well, to identify the methods that the teachers use to upgrade their skills in the areas of STEM. Teachers could be queried about whether they are aware of the PL opportunities provided such as: after school training run by their school district consultants/coaches, summer institutes offered by their school district consultants/coaches, and alternatives like AQ courses provided online and in-person at universities as well as through their unions. The perspective of the teacher unions might be garnered with respect to what their expectation is for members to be lifelong learners in STEM education. In the past few years, funding has been provided to teachers to encourage them to take additional qualification courses in Mathematics, Computer Technology, and Special Education. How will PL in transdisciplinary methods and STEM education be supported?

Additional research needs to be done with regards to documenting how coaches and consultants get trained to be professional learning facilitators. Educational research might investigate what training is provided to ensure that coaches/consultants are current in their knowledge and facilitation skills as well as cross-subject coaching collaboration. A case study might be set up to compare single discipline or curricular area coaching to coaching in STEM/STEAM and transdisciplinary approaches. There are several current coaching models and research papers describing successful coaching techniques; how would these be applied if coaches were collaborating with each other? How should coaches and consultants be engaged in formal professional learning?

Research into coaches' professional learning should begin with asking the coaches and consultants what support and preparations they were provided when they stepped into their role. This should be followed by an account of what PD and PL coaches and consultants have taken in two ways: board-initiated and self-initiated. More work should be done with the researchers following the coaches and consultants, to identify areas of strength and areas of need in supporting their ongoing professional learning needs. Most importantly coaches and consultants should be demonstrating the traits required to be an effective coach (Knight, 2007). Professional learning projects with certification to demonstrate their knowledge and understanding of what traits the coach needs to have might be implemented. Researchers could consider how to investigate the evolving coaching practices of establishing strong, trusting relationships, being flexible and open to teachers and their student needs, meeting teachers where they are at and working collaboratively with them to move them forward, and helping teachers build their confidence and content knowledge for the gradual release of responsibility.

Limitations

When interpreting the findings of a study it is important to note that there are limitations that are inherent in most studies. Limitations for this current study included the teacher participants' familiarity with the PSI/STEM Coach and the location and the small population size of the school board. The teachers who volunteered to take part in this study were all known to the PSI/STEM Coach in the capacity of working for the same school board. Although the PSI/STEM Coach had not worked with three of the six in their classes and did not know them personally, the other three teachers were familiar to the PSI/STEM Coach who had worked with them in one off sessions in their classes in the previous school year (in 2021-2022) and online with Google Meet and the Virtual learning environment during COVID (in 2020). Future research should take place at a school board where the PSI/STEM Coach is not familiar to the staff.

There were a limited number of PL sessions with six teachers involved in this study, which may have limited the impact of the coaching. Another consideration is the demographic location of the school board is discrete and its teaching staff are predominantly Caucasian. Even though the school communities where the teachers were from were diverse in socio-economic and student populations, lack of diversity is a limitation for the current study. As well, five of the teachers self-identified as female and one teacher self-identified as male. Future research should take place in school boards where there is a greater diversity among hired teachers as well as a range of experience levels. All six of the teachers in this study were teaching for over 10 years.

Conclusion

With changes happening in the real-world such as climate change, economic hardship and war, there is heightened discussion about the expectations that are now on teachers to prepare their students for an uncertain future. Teachers, both experienced and novice, need to have ongoing support through PL and coaching to help them integrate into their instruction contemporary curriculum and topics and the expectations they are required to meet to support the 21st century learning of their students. Given the density of the curriculum, complexity of topics and with limited hours in the school day, teachers need to begin to shift their practices from single subject silo teaching to incorporating a balance of transdisciplinary and cross-curricular learning. They can do this with the support and partnership of coaches, who are well trained and prepared. Teachers also need to see the value they bring to the classroom experience, be open-minded, and shift their beliefs to identify their own strengths. Ultimately, it is the students who benefit from the outcomes of strong, positive, and innovative teaching practices.

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Appendix A

Letter of Invitation for Participants (Emailed)

Dear Participant,

I would like to invite you to participate in an independent research study that I am conducting, as a part of your STEM curriculum sessions experience. The purpose of my research is to identify what areas can be improved with regards to Digital Learning and Science Coach interaction, and understanding how to support you, the classroom teacher. The research is not looking at your students or their performance outcomes.

The research study would involve you filling in one pre-session Google form questionnaire which refers to your STEM experience and the 2022 Grade 1-8 Science curriculum, and one post-session Google form questionnaire and a 10–15-minute one-on-one recorded interview where you will be asked 4 questions. This interview will be conducted by me at the conclusion of Session 5 at a time that fits your schedule. You will be also asked to send me samples of your work such as screenshots of your coding story, of your desktop grid, and/or the digital grid.

All of this is voluntary on your part and does not interfere with the sessions being offered to you and your students. Should you choose not to participate or to stop participating at any time, the coding sessions will still run for you and your students.

All information and responses collected will be completely confidential and you will have full access to the transcripts of what you said.

Thank you for considering participating,

Much appreciated,

Heidi-Ann Pöltl

Principal Student Investigator:
Heidi-Ann Pöltl, MEd Candidate
Brock University
(905) 941 0203
hp95aa@brocku.ca

Principal Investigator/Faculty Supervisor:
Dr. Tiffany Gallagher
Brock University
(905)688-5550 Ext: 5114
tgallagher@brocku.ca

Appendix B

Participant Consent Form

Date: February 2023
Project Title: Understanding grade 4-8 teachers' instructional practices and beliefs as a function of transdisciplinary coaching in STEM and literacy education

Principal Student Investigator (PSI): Heidi-Ann Pöltl, Master of Education Candidate, Brock University, (905) 941 0203, hp95aa@brocku.ca

Principal Investigator/Faculty Supervisor: Tiffany Gallagher, Professor, Department of Educational Studies, Brock University, (905) 688-5550 Ext. 5114, tgallagher@brocku.ca

INVITATION

You are invited to participate in a study that involves research. The purpose of my research is to identify what areas can be improved with regards to Digital Learning and Science Coach (DLSC) interaction and support of your practice as a classroom teacher. [KJJ1] The research is not looking at your students or their performance outcomes. Note that the DLSC is also the Principal Student Investigator (PSI) and she is doing research as part of her graduate studies.

WHAT'S INVOLVED

Should you choose to participate, you will be asked to participate in data collection related to five sessions of STEM and literacy education. Prior to the coaching you will be asked to complete one pre-session Google form questionnaire which will ask you about your STEM, coding and engineering design process experience. There are 12 questions to complete and this will take approximately 10 minutes. You will have one week to complete this questionnaire on your own time. This will help the researcher (PSI) understand your knowledge, skills and beliefs about teaching STEM with literacy, and including coding and the engineering design process prior to beginning research.

After each of the five sessions of coaching, the PSI (DLSC) will be making audio recorded notes in the privacy of her home with respect to her own practice as a coach and the perceived impact that she had on the sessions. This is a form of researcher reflection and will be used as data.

As well, a follow up email from the PSI (DLSC) is sent to you after each session. The PSI (DLSC) will continue to offer you support and any extra resources that you might need. After each session, you will be asked to send (via email attachment using your school board email) to the PSI (DLSC) artifacts such as screenshots of your coding story, your desktop grid, and/or the digital grid. This is evidence of your instructional practice and learning. These artifacts are not student-produced and do not have any identifying information related to your students.

After the final coaching Session 5, you will be asked to complete a post-session Google form questionnaire which will ask you about your experience with the DLSC and your intentions regarding your future instructional practice with coding.There are 10 questions to complete and this will take approximately 10 minutes. You will have one week to complete this questionnaire on your own time.

Finally, after Session 5, you will be asked if you with to do a 10-15 minute one-on-one interview where you will be asked five questions about the coding sessions, the support that you received from the PSI (DLSC), and your future teaching practice related to coding.This interview will be conducted by the PSI (DLSC) at a time that fits your schedule. The interview will take place at your school, in a semi-private area (e.g., your classroom when no students are present). The interview will be audio recorded and transcribed by the PSI (DLSC) and used as results in the study.

You will be referred to with a gender-neutral pseudonym. Overall, the total time for your participation will take 30-35 additional minutes (for the two questionnaires and one interview and 15 optional minutes to review your interview transcript). Your time with the DLSC coach is considered professional learning and not included in the time dedicated to study participation.

POTENTIAL BENEFITS AND RISKS
The research will benefit your knowledge of STEM teaching with literacy. It will also benefit your coding and engineering design thinking within your classroom and will allow you to reflect on your coaching and instructional practices. This study will also benefit your understanding of students' real-world problem-solving skills as well as provide ways to use the transdisciplinary approach with your curriculum. You will be encouraged to harness other instructional learning opportunities. This knowledge [KJJ2] is transferable, as it could be implemented with different grades and subjects.

CONFIDENTIALITY
All information you provide is considered confidential; your name will not be included or, in any other way, associated with the data presented in study reports. Any information that you provide related to your students' learning is confidential and is not relevant to the findings in this study. The interviews will be audio recorded, however a chosen gender-neutral pseudonym will be used for you. With regards to the data collected, with your permission, anonymous quotations may be used. Shortly after the interview has been completed, a copy of the transcript will be mailed or emailed to you (identify choice below) to give you an opportunity to confirm the accuracy of the conversation and to add or clarify any points that you wish. You will have three weeks to review your transcript; this process should take approximately 15 minutes of your time. If you fail to return the transcript, then it is assumed that you are satisfied with the transcript 'as is.'

Data collected during this study will be stored in a locked filing cabinet or a password protected personal computer of the PSI (DLSC). Data will be kept for one year after the completion of the study in which paper documents will be shredded and computer files will be deleted and removed from the trash bin. Access to these data will be restricted to Heidi-Ann Pöltl and Tiffany Gallagher (Supervisor). In rare cases, it will not be possible to ensure confidentiality because of mandatory reporting laws (e.g. suspected child abuse, reported communicable diseases) or the possibility of third-party access to data (e.g., court subpoena of records). This is a potential limitation with regards to confidentiality that you should be made aware of.

VOLUNTARY PARTICIPATION
Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study. Further, you may decide to withdraw from this study at any time and may do so without any penalty or loss of benefits to which you are entitled. In the event of a withdrawal, data will be destroyed upon request.

PUBLICATION OF RESULTS
Results of this study may be published in professional journals and presented at conferences; as well, the results may be presented as part of Heidi-Ann Pöltl's graduate studies. Feedback about this study will be made available six months after the conclusion of the research by sending the results via your preference of email or mail, if interested.

CONTACT INFORMATION AND ETHICS CLEARANCE
If you have any questions about this study or require further information, please contact Heidi-Ann Pöltl at hp95aa@brocku.ca or 905-941-0203 OR Tiffany Gallagher at tgallagher@brocku.ca or 905-688-5550 ext. 5114. This study has been reviewed and received ethics clearance through the Research Ethics Board at Brock University ****. If you have any comments or concerns about your rights as a research participant, please contact the Research Ethics Office at (905) 688-5550 Ext. 3035, reb@brocku.ca

Thank you for your assistance in this project. Please keep a copy of this form for your records.

CONSENT FORM
If you have any questions about this study or require information, please contact Heidi-Ann Pöltl or Tiffany Gallagher using the contact information above. If you have comments or concerns about your rights as a research participant, please contact Brock University Research Ethics Office (905 688-5550 ext.3035, reb@brocku.ca) quoting ***** This study has been reviewed and received ethics clearance through the Research Ethics Board at Brock University.

I agree to participate in the study described above. I have made this decision based on the information I have read in the Participant Consent Form. I have had the opportunity to receive any additional details I wanted about the study and I understand that I can ask questions in the future. I understand I may withdraw consent at any time.

- Yes
- No

Name (printed): ________________ Signature: _____________________Date: __________
I wish to have my interview transcript:
- Mailed to: __________________________________
- Emailed to: _________________________________

I wish to have the results of the research:
- Mailed to: __________________________________
- Emailed to: _________________________________

Appendix C

Pre-Session Teacher Questionnaire

All information from the survey is kept confidential.

Question 1: Name (First and Last)

Question 2: Grade teaching (4-8)

Question 3: Do you incorporate literacy into your STEM lessons? yes/no

Question 4: If yes, how often do you incorporate literacy into your STEM lessons (reading stories, news articles, research papers relating to STEM content).
Occasionally (once in a strand), Frequently (2-3 times in a strand), every lesson

Question 5: Do you teach science by strand? yes/no

Question 6: Rank [TG4] the science strands in order of comfort level for teaching. 1 being most comfortable, 5 being least comfortable.

Question 7: Do you teach math by strand? yes/no

Question 8: Rank the mathematics strands in order of comfort level for teaching. 1 being most comfortable, 5 being least comfortable.

Question 9: Are you comfortable with the engineering design process? yes/no

Question 10: Rank your coding experience. 1: not comfortable at all 3: very comfortable

Question 11: Have you worked with the DLSC before? yes/no

Question 12: If yes, what sort of impact do you feel the DLSC had with your instructional practices? Not that much, some growth, meaningful growth, lots of growth.

Question 13: Any other comments you would like to share.

Appendix D

Post-Session Teacher Interview Questions

Teacher Interview Questions: recording will be made using Google Meet transcript.

Part A: Interview by: PSI/STEM Coach

1: Describe to me any changes that you have made to your teaching STEM-L (STEM with Language) over the sessions we worked together. What do you perceive to be the impact of these changes to your teaching practices?

2: Reflecting back to before you participated in DLSC coaching, how do you feel now about teaching STEM-L?

3: We worked with the engineering design process and with reaching out to community partners for support during this process. What are your impressions about this process and outcome?

4: From the start of the sessions to now, how do you feel your coding experience has changed, for unplugged and plugged?

5: How do you feel these sessions and the practices impacted on your student outcomes?

6: From the sessions and STEM-L what do you perceive regarding student engagement?

7: Have you altered any aspects of your assessment and/or instructional practices since you began working on this project? If so, please describe your changes and their effects.

8: What was your greatest accomplishment throughout this project?

9: Describe your most successful interaction during this project. What factors do you think affected this experience?

10: What was the most insightful, profound, or revealing moment(s) for you throughout this project?

11: Do you think that participating in this project has affected your beliefs about effective teaching? If so, please describe these changes.

12: Throughout the project what have you learned about yourself as a teacher? What key insights will you take from this experience into your teaching career?

13: What are some future coaching collaborations you would like to engage with?

Part B: "Post-session Interview" by Supervisor: Tiffany Gallagher with teachers about PSI/STEM coach experience

Background and Demographics

1. Tell me about yourself as a teacher. How many years have you been teaching and in what school settings have you taught? What grades have you taught?
2. What are your greatest strengths as a teacher? What are your greatest challenges as a teacher?

Professional Development Context and Overall Impressions

3. Tell me about your experiences as a participant in the Digital Coaching project (with Heidi) to date. What was the focus of the sessions and how did they support you and your students? If someone outside of the project were to ask you describe the focus and activities of the project, what would you tell them?
4. How and why did you become involved in the Digital Coaching project? What did you hope to accomplish during the project?

Teacher PD/Coaching Practices

5. Have you seen changes in student motivation, work, and/or achievement as a result of changes in your practice that are a function of your work with the DLSC during this project?
6. What factors do you believe contribute to effective teacher professional development and/or coaching?

Concluding Thoughts

7. If feasible, do you plan to continue to work with your Digital Technology and Science coach (Heidi) in the future? If so, what professional learning goals and objectives do you have and what support will you require in accomplishing your goals?
8. If you had the opportunity to be able to choose to continue in this project for the forthcoming school year or not, would you continue as a participant? Why or why not?

Appendix E
Certificate of Ethics Clearance for Human Participant Research

Brock University
Office of Research Ethics
Tel: 905-688-5550 ext. 3035
Email: reb@brocku.ca

Social Science Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE: 4/13/2022

PRINCIPAL INVESTIGATOR: GALLAGHER, Tiffany - Educational Studies

FILE: 21-252 - GALLAGHER

TYPE: Masters Thesis/Project STUDENT: Heidi Poltl

SUPERVISOR: Tiffany Gallagher

TITLE: Understanding Teachers' Beliefs and Practices about
Coding and Computational Thinking through Digital Learning Coaching

ETHICS CLEARANCE GRANTED

Type of Clearance: NEW Expiry Date: 4/1/2023

The Brock University Social Science Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from **4/13/2022 to 4/1/2023.**

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 4/1/2023. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Office of Research Ethics web page at: https://brocku.ca/research-at-brock/office-of-research-services/research-ethics-office/#application-forms.

In addition, throughout your research, you must report promptly to the REB:

a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study; b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
c) New information that may adversely affect the safety of the participants or the conduct of the study; d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.
Approved:

Angela Book, Chair
Social Science Research Ethics Board
Dipanjan Chatterjee, Chair
Social Science Research Ethics Board

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.