

**TEAMWORK MAKES THE DREAM WORK: TEACHERS’
EXPERIENCES WITH INTERDISCIPLINARY INTEGRATION IN
TECHNOLOGICAL EDUCATION**

by

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Abstract

Though enrollment rates into many of TE and BBT programs have seen some decline, mostly due to revised requirements for the Ontario Secondary School Diploma (OSSD), learners still stand to benefit from exposure and learning in both academic and TE learning streams. The TechnoMath program was a collaborative effort between the Ontario Ministry of Education and a school board in Southern Ontario to support integrated teaching and learning between TE and mathematics. In this program, TE and mathematics teachers were assigned to work collaboratively to develop and teach an integrated curriculum combining a TE subject area within Grade 10 mathematics. The purpose of this study was to examine how these teachers applied interdisciplinary teaching in their collaborative practice and how they navigated challenges throughout its implementation. A qualitative case study methodology was used to respond to the following research questions: (1) How do two teachers collaborate to deliver an integrated TE and academic mathematics program? (2) What challenges do teachers face during integrated teaching of the TechnoMath program, and how do they navigate these challenges? and (3) What perceived benefits and weaknesses do teachers identify in the TechnoMath program?

These research questions were explored using teachers' perspectives as examined through participant-observations, document analysis (i.e., curricular materials), field notes, and semi-structured interviews. This case study described an integrated teaching model in which TE and academic subjects were delivered with consideration for how teachers navigated challenges to integrated teaching and learning.

Data were open-coded using NVivo software; the codes mapped onto seven themes after analysis. These themes were: (1) Teachers' readiness; (2) Assessment; (3) Student experience and learning; (4) Subject integration; (5) Curricular content; (6) Collaborative practice; and, (7)

Financial and planning challenges. Research found that collegial collaboration was present and essential in helping participants overcome challenges faced as a result of teaching an integrated program. TechnoMath also allowed teachers to deliver larger scale projects as a result of their collaboration, though student engagement was not as high as expected. Planning time, assessment strategies, and logistics surrounding procurement of project materials were the main challenges faced by teachers.

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Table of Contents

Abstract.....	ii
Acknowledgements.....	iv
List of Figures.....	viii
List of Tables.....	ix
List of Abbreviations.....	x
Chapter 1 Introduction.....	1
1.1 Purpose and Research Questions.....	7
1.2 Key Terms.....	8
1.3 Thesis Structure.....	9
Chapter 2 Literature.....	10
2.1 Introduction.....	10
2.2 Subject Integration.....	10
2.3 Review of Subject Integration.....	15
2.4 The TechnoMath Program as Interdisciplinary Learning.....	18
2.5 Teacher Collaboration.....	20
2.6 Teacher Collaboration in the TechnoMath Program.....	26
2.7 Technology and Mathematics Education.....	27
2.8 Summary of Literature.....	29
Chapter 3 Methods.....	31
3.1 Research Design.....	31
3.2 Research Site and Participant Selection.....	32
3.3 Data Collection.....	33
3.3.1 Classroom, Planning Session, and TechnoMath Orientation Observations.....	34
3.3.2 Artifacts.....	35
3.3.3 Interview Structure.....	35
3.3.4 Confidentiality.....	36
3.4 Data Analysis and Representation.....	36
3.4.1 Emergent Codes.....	37
3.4.2 Emergent Themes.....	39
3.5 Reflexivity, Triangulation, Validity, and Limitations.....	40
Chapter 4 Results.....	42
4.1 Introduction.....	42

4.2 Teacher’s Readiness to Implement TechnoMath.....	42
4.2.1 Teacher Experience	43
4.2.2 TechnoMath.....	44
4.3 Assessment	45
4.4 Student Experience and Learning.....	49
4.4.1 Engagement	49
4.4.2 Student Experience	51
4.4.3 Transferable Skills.....	53
4.5 Subject Integration.....	54
4.6 Curricular Content	56
4.7 Collaborative Practice and Challenges	60
4.7.1 Collaborative Challenges.....	63
4.8 Financial and Planning Challenges.....	67
4.9 Summary of Key Findings.....	69
Chapter 5 Discussion	72
5.1 Introduction.....	72
5.2 Teacher Collaboration and Subject Integration in TechnoMath.....	73
5.2.1 Subject Integration—Its Implementation, Challenges, and Benefits.....	74
5.2.2 TechnoMath’s Strong Start.....	77
5.2.3 The Need for Administrative and Ministerial Support	79
5.2.4 Teacher Collaboration—How Teachers in TechnoMath Worked Together	79
5.2.5 Pooling Skills to Excel as a Team	81
5.2.6 Professional Workspace and Assessment in the Context of Collaboration: Together but still Separate.....	82
5.3 Practical Challenges with TechnoMath.....	84
5.3.1 Logistical Challenges.....	84
5.3.2 The Added “Burden” of Collaborative Planning and Associated Temporal Constraints.....	85
5.4 Contribution	86
5.5 Limitations	87
5.6 Recommendations for Future Research.....	88
5.7 Conclusion	91
References.....	94
Appendix A Sensitizing Concepts	102
Appendix B Interview Questions.....	103

Individual Interview Questions.....	103
Group Interview Questions.....	105
Appendix C Queen’s University Ethics Clearance.....	106
Appendix D Letters of Information and Consent Forms.....	107

List of Figures

Figure 1 The Multidisciplinary Approach	11
Figure 2 The Interdisciplinary Approach	12
Figure 3 The Transdisciplinary Approach.....	14

List of Tables

Table 1 Code Frequency Table.....	38
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List of Abbreviations

Broad-Based Technology – BBT

English Language Learning – ELL

Math Teacher – MT

Ontario Secondary School Diploma – OSSD

Ontario Secondary School Literacy Test – OSSLT

Technological Education – TE

Technology Teacher - TT

Chapter 1

Introduction

I was first thrust into the ESL teaching world soon after I graduated from university—this was my first experience in front of the classroom. As an ESL teacher, my success was highly dependent on student engagement. The more engaged the students, the more likely they would practice and subsequently improve their English fluency. I found the most effective way to engage students was to teach them English through subjects and topics that they would be interested in. This method involved a classroom environment where students applied “skills, knowledge and attitudes of different disciplines to a single experience, theme or idea ... it also incorporates the interdisciplinary dimension of linking subjects to develop conceptual insight into particular phenomena” (Parker, Heywood, & Jolley, 2012, p. 694). This method is often referred to as interdisciplinary integration (Barnes, 2007). Using history or geography as a method of content delivery within the context of the English language, for example, would pique my students’ interest more than if I were to explicitly describe the present perfect or tell them what a past participle is. When I left ESL instruction and began working as a cook, only to return to teaching in the field of TE several years later, I brought these lessons with me. Working within the area of Hospitality and Tourism, it became evident to me how learners are exposed to principles of mathematics, chemistry, and physics while engaging in the TE curriculum, whether the students know it or not. As a TE teacher now—and as I supply taught in classrooms while writing this thesis—I started to see the benefit of interdisciplinary learning in my own practice. My orientation

as a teacher is to engage in interdisciplinary instruction whenever possible and to encourage my students to draw on their knowledge of other subjects when interacting with my own assignments and classroom materials. Specifically, I value the process of connecting TE curriculum with other curricular strands to both demonstrate the relevance of curriculum to students and to deepen their learning about TE concepts and practices.

The TE curriculum in Ontario consists of ten broad-based technology (BBT) subject areas: Communications Technology, Computer Technology, Construction Technology, Green Industries, Hairstyling and Aesthetics, Health Care, Hospitality and Tourism, Manufacturing Technology, Technological Design, and Transportation Technology (Ontario Ministry of Education, 2009). Theodore Lewis (1999) describes the main component of TE as “learning by doing” and posits that it is through this type of learning that TE can reinforce deep understanding of its core concepts (p. 12). The Ontario TE curriculum document echoes this sentiment: “The philosophy that underlies broad-based technological education is that students learn best by doing” (Ontario Ministry of Education, 2009, p. 5). Further, Lewis (1999) emphasized that Technology Education can provide context for “the general curriculum’s way to connect it with the human-made world” (p. 12). Subjects like mathematics, chemistry, physics, and English, among many others, are easily integrated into the TE environment and can provide students with valuable experiential learning opportunities (Venville, Wallace, Rennie, & Malone, 2000).

Science and mathematics, in particular, are very well suited to integrated programs due to their “applied nature” (Venville et al., 2000, p. 24), which was shown in a case study in which a student was taught mathematical concepts through a physics

experiment: “The experience of applied mathematics, during, physics, provided Michael with opportunities for building mathematical concepts that became believable” (p. 24).

This idea of believability most likely stems from the often proclaimed sentiment students can be heard making during math lessons regarding the practicality of concepts learned—“when am I ever going to use this in real life?”—through applying math concepts in other subject areas, students can more easily see the real world value of their learning. A student from a former study echoes the logic involved in subject integration when they stated, “you can’t do math without grabbing a piece of wood,” referring to the usage of math within their own construction class (Hill & Smith, 2005, p. 28).

Ontario provincial education policy centers on building competencies that emphasize critical thought, communication, collaboration, creativity, and innovation (Ontario Ministry of Education, 2015). Integration of TE into the academic curriculum serves as one vehicle through which students can achieve these goals while introducing them to the real-world application of sometimes abstract concepts, and thus, “strength[en] students’ competencies in academic subject areas, critical thinking, and problem solving ... ensuring that students learn academic content in ways that are relevant ... by providing other contexts in which the theory has meaning” (Conroy & Walker, 2000, p. 55; Hoachlander, 1999; Underhill, 1995; Vars, 2001; Venville et al., 2000). A seminal study into subject integration conducted between 1930 and 1942, known as The Eight-Year Study, also demonstrated that students educated within an integrated teaching framework were “strikingly more successful” than their counterparts who engaged in a more traditional, subject-segregated model of education (Drake, 2012, p. 7). Moreover, the students within the integrated system demonstrated more engagement, motivation,

better attendance, and required less classroom management due to disciplinary issues than their traditional education counterparts (Drake, 2012).

Learners stand to benefit from the integration of academic and TE learning streams. Student achievement is increased for those who do not typically fare well in academic or traditional curricula—students can “benefit from integrated instruction that solidifies and deepens their understanding of academics” (Hoachlander, 1999, p. 4). When both streams are integrated, a “cognitive synergism” is developed where TE related activities are reflected upon through an academic lens (Kincheloe, 1999, p. 254). Further, this integrated classroom structure often mirrors potential future workplace environments more so than traditionally academic lessons, and therefore, may better prepare students for environments and situations they are likely to encounter in their professional futures (Kincheloe, 1999; Hoachlander, 1999).

In spite of the research supporting integration of academic and TE curricula, “only one-fifth of high schools surveyed in 1994 reported that they have ‘some’ use of integration, and more than half offered no integration at all” (Conroy & Walker, 2000, p. 55). Integrating TE curriculum with other subjects has also been made increasingly difficult as enrollment in its programs has continued to decline over the years in favour of more academically oriented curricula (Smaller, 2003). In Ontario, this decline is mostly due to revised requirements for the Ontario Secondary School Diploma (OSSD) (Smaller, 2003). These requirements refer to students needing to take either a compulsory arts or a TE course pre-1999 in Ontario. This selection increased the probability of TE enrollment as compared to current OSSD requirements which require a compulsory choice of only

one of the following five courses: science (Grade 11 or 12), TE, French, computer studies, or cooperative education.

In understanding the classroom and school environment, as well as the student and teacher experiences that occur within them—the sites in which interdisciplinary integration take place—and in reflecting on associated difficulties with interdisciplinary and collaborative methods of instruction, teachers and administrators can better understand how to integrate academic curricula within a TE framework. In an integrated teaching environment, the collaboration between teachers is just as important as it is between teachers and students. Collaboration here is defined as the “joint interaction in the group in all activities that are needed to perform a shared task” (Vangrieken, Dochy, Raes, & Kyndt, 2015, p. 23). Vangrieken et al. (2015) expand on the types of collaboration frequently used by teachers. They argue that collaboration is “often restricted to discussing ideas and materials” but seldomly involves discussing “problems teachers meet in their daily practice, observing each other in the classroom, discussing each other’s functioning, and critical examination of teaching” (p. 27). Teaching is frequently a solitary practice as teachers “often act alone in their work of teaching pupils and evaluating their work,” placing “restrictions on the potentially positive synergies that can exist between teachers” (Christophersen, Elstad, & Turmo, 2011, p. 640). Teacher-teacher collaboration has been shown to have many positive outcomes. These include improvement of student understanding and performance, higher rates of teacher motivation, decreased workloads, increases in morale, and more student-centred learning (Vangrieken et al., 2015, p. 27). These outcomes are echoed in the research of Christopherson et al. (2011) in which they found “strong positive associations” between

teacher-teacher trust and peer collaboration (p. 647). Further, they assert that these positive attitudes are regarded as “core resources for the work of improving schools” (p. 648). In order to promote the type of inter-departmental cooperation that is required of integrated instruction, staff collaboration must also be of prime concern. A notable barrier of entry into interdisciplinary teaching is subject knowledge. Zolnierczyk (2016) found that in order to successfully integrate subjects, teachers must be more knowledgeable in multiple subject areas. This barrier can be overcome if teachers combine their knowledge collaboratively in an integrated teaching model.

While there is ample research into the efficacy of integrated models of curriculum— particularly in the science, technology, engineering, and mathematics (STEM) fields—as well as work done on collaboration, there are gaps in the literature when these subjects are examined within the context of curricular programs involving TE. “There is rich literature in the field on curriculum ... But there is need for an empirical counterpart to this literature, the greatest of which might be for case studies that focus upon actual instances of attempts at curriculum change, where school districts, schools, or particular teachers could be the unit of analysis” (Lewis, 1999, p. 10). Specifically, examining teachers’ collaborative practices to integrate academic subjects— particularly within the STEM field—with those of the TE curriculum in official, board-sanctioned programs is lacking (Stubbs & Meyers, 2015). Accordingly, the purpose of this thesis research is to begin to address this gap in research by examining how two teachers collaborate within an integrated technology-mathematics program.

One such program that sought to use teacher collaboration and the integration of mathematics and the TE curriculum to the benefit of learners is the TechnoMath program

in Ontario. This program was a collaborative effort between the Ontario Ministry of Education and a school board in Eastern Ontario. In it, TE and mathematics teachers were assigned to work collaboratively to develop and teach an integrated curriculum combining one of the Broad-Based Technology (BBT) subject areas in conjunction with the mathematics curriculum. Specifically, this program combined the BBT subject of construction with mathematics. Structurally, the program relied on the consecutive scheduling of construction and math classes in the students' and teachers' timetables. This allowed teachers to teach concepts in their respective classes that complemented each other's lessons. The teachers were tasked with working collaboratively to design and implement lessons that highlighted the synergies between the two subjects in an attempt to both reveal mathematical concepts in the real world and to offer a deeper understanding of the mathematical principles that underpin their construction projects. The TechnoMath program was piloted in 2017 and has subsequently been implemented in one school within an eastern Ontario school board.

1.1 Purpose and Research Questions

The TechnoMath program provides an ideal context to explore teacher collaboration across academic and TE subjects – an area which has yet to be fully explored in the literature. Accordingly, the purpose of this case study research was to examine how teachers in the TechnoMath program collaboratively applied integrated teaching within the program and how they navigated enactment challenges throughout the implementation of this program in an Eastern Ontario high school. Hence, this study involved exploring integrated teaching practices and professional collaborative

relationships among TE and academic teachers. Guiding this study were the following research questions:

- (1) How do two teachers collaborate to deliver an integrated TE and academic mathematics program?
- (2) What challenges do teachers face during integrated teaching of the TechnoMath program, and how do they navigate these challenges? and
- (3) What perceived benefits and weaknesses do teachers identify in the TechnoMath program?

1.2 Key Terms

Key terms associated with this study are collaboration, subject integration, team, TechnoMath, and TE. Collaboration refers to the “joint interaction in the group in all activities that are needed to perform a shared task” (Vangrieken et al., 2015, p. 23). Subject integration refers to the combining of two or more subjects or disciplines within a teaching curriculum to be delivered by either single or multiple teachers within the confines of their own disciplines or across them—types of integration discussed in the literature review include multidisciplinary, interdisciplinary, and transdisciplinary approaches. Team is used to refer to the unit of teachers involved in conducting the TechnoMath program. A team is defined as “a collection of individuals who are interdependent in their tasks, who share responsibility for outcomes, who see themselves and who are seen by others as an intact social entity embedded in one or more larger social systems” (Vangrieken et al., 2015, p. 25). TechnoMath refers to the name of the program being studied in this work. It is a collaborative effort between the Ontario Ministry of Education and a school board in Southern Ontario. In this program, a team of

TE and mathematics teachers is assigned to work collaboratively to develop and teach an integrated curriculum combining one of the TE BBT subject areas with the Grade 10 mathematics curriculum. TE refers to a high school curriculum in Ontario consisting of ten broad-based technology (BBT) subject areas: communications technology, computer technology, construction technology, green industries, hairstyling and aesthetics, health care, hospitality and tourism, manufacturing technology, technological design, and transportation technology (Ontario Ministry of Education, 2009). It centres on project-based learning and can also be used as an introduction to vocational training programs at the college level.

1.3 Thesis Structure

This thesis will be structured into 5 chapters, with the first chapter being the introduction to the work. Chapter 2 examines the literature relating to the topics of teacher collaboration and subject integration—the two most pertinent points associated with the examination of the TechnoMath program. Chapter 3 explores the methodology, as well as an introduction to the participants and site selection for this study. In chapter 4, I present and analyse findings from the data collected through observations, document collection, and interviews by presenting emergent themes connected with teachers' experiences while delivering the TechnoMath program. Chapter 5 ties the preceding analysis with the literature and research questions of the study.

Chapter 2

Literature

2.1 Introduction

In order to support my study on teachers' collaborative efforts in their delivery of an integrated curriculum program, I reviewed literature related to the topics of subject integration and teacher collaboration with a focus on secondary school application. An understanding of subject integration helped focus field observations and facilitated understanding of techniques used by teachers in the implementation of the TechnoMath program, the focal program of this study. Further, as TechnoMath is contingent on collaboration between teachers from different subject areas and skills to cooperatively deliver curricular content that compliments and enhances student understanding of the subjects being explored, related literature on teacher collaboration provided a necessary foundation for this study.

2.2 Subject Integration

As there are so many variants of subject integration, it was important to have a working definition for this study in order to guide the focus of this research. Three main approaches to integration were identified in the literature—Multidisciplinary, Interdisciplinary, and Transdisciplinary (Drake & Burns, 2004; Loepp, 1999).

Multidisciplinary integration typically centres various subjects on a unifying theme through a variety of approaches—as seen in Figure 1. Within this framework, the various disciplines, or subject areas remain “very distinct”, though “deliberate connections” are drawn between them (Drake, 2012, p. 15). A clear example of this style

of subject integration in high school would be the study of World War II in History class while examining the novels *Catch-22* or *Maus* in English class—the subject matter is unified by a common theme, yet the classes and subjects themselves are still independent of each other. This form of integration is sometimes referred to as parallel curriculum (Drake, 2012). From a teaching standpoint, there is not much collaboration required between teachers in order to properly execute this type of subject integration—while the themes explored are similar or identical, the subject matter itself (i.e. historical accounts, literary devices, etc.) remains “firmly within an intact subject”—History and English, in the case of our previous example (Drake, 2012, p. 16). Usage of this kind of integration also means that subject content and student assessment do not require much modification when transitioning from a traditional subject-segregated model to a multidisciplinary one. Drake (2012) states that when using this approach, it is common to expect the students to make the connections with various subjects rather than having the teachers explicitly pointing them out for them.

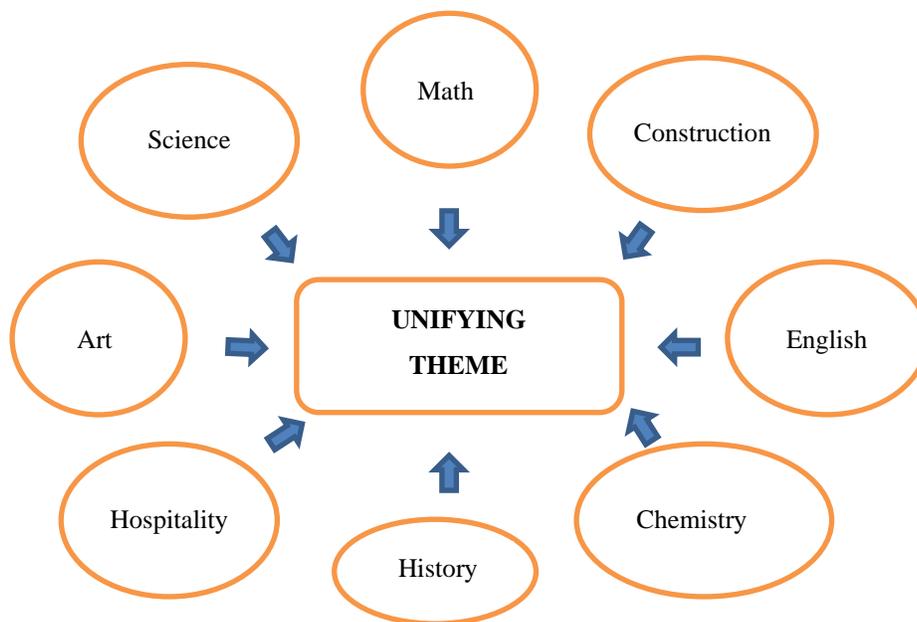


Figure 1 The Multidisciplinary Approach

Interdisciplinary integration is another one of the three main approaches to subject integration (Drake & Burns, 2004). Interdisciplinary integration puts less focus on the individual disciplines—something which the Multidisciplinary method does not—in favour of identifying the skills and knowledge in which they are rooted, as seen in Figure 2. In this approach, curriculum still centres on a common theme across the subject areas, though this theme is usually more of a “universal concept” than in the Multidisciplinary approach (Drake, 2012, p. 18). The Interdisciplinary approach emphasizes the learning and reinforcing of the underlying concepts present in subject matter across various disciplines (Drake & Burns, 2004). Literacy and numeracy skills, “big ideas,” thinking and research skills, and enduring understandings are examples of these underlying concepts (Drake, 2012, p. 19).

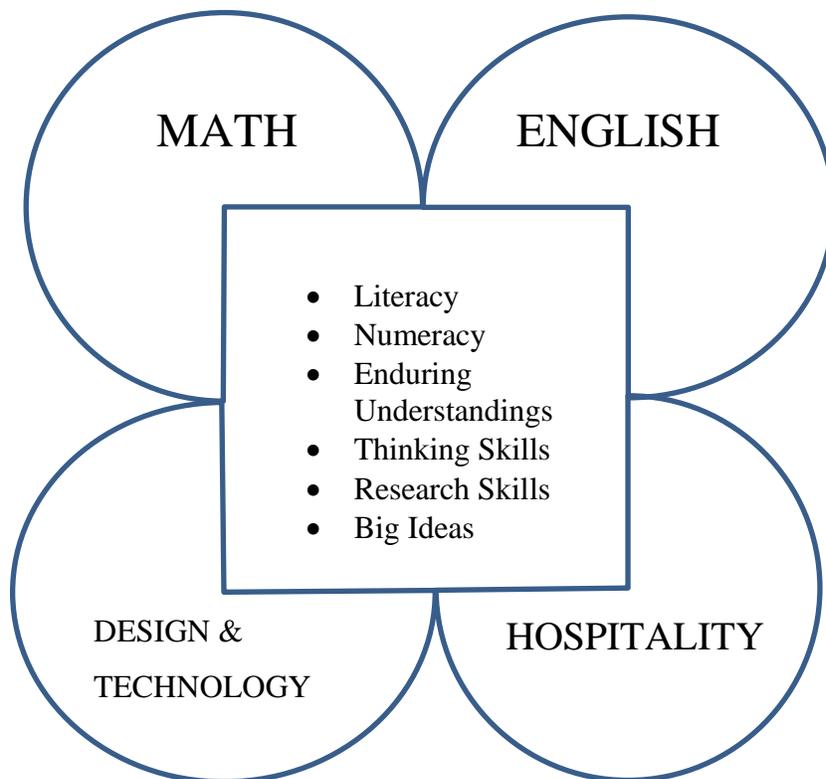


Figure 2 The Interdisciplinary Approach

Murray and Bellacero (2008) describe a project in which they used interdisciplinary integration with mathematics and English to reinforce writing and mathematics skills for Grade 8 students. In this project, students were asked to observe styles of writing in gossip magazines and tabloids and then apply those same styles to a story involving mathematical concepts as the main subject. Titles created by the students during this project— “Hypotenuse caught in love triangle” and “Polynomial weight loss system,” among others—demonstrated not only clever writing skills, but also a grasp of mathematical language through the usage of puns (Murray & Bellacero, 2008; Drake, 2012, p. 19). The products of this project received praise from both the mathematics and English teachers involved in the project.

The Transdisciplinary approach of integrating curriculum is developed by the teacher and based around students’ questions (Drake & Burns, 2004). The driving principle behind this method of integration is to provide the learners with real-life context, and the “perceived relevance for the students” is the most important factor in determining curriculum—see Figure 3 (Drake, 2012, p. 20). In this approach, the distinctions between subject areas become blurred as student inquiry takes precedence over traditional subject topics as the defining characteristic of curricular design. Project-based learning, a scenario in which students “tackle a local problem”, is one of the most known types of Transdisciplinary integration (Drake & Burns, 2004, p.13). As such, the Transdisciplinary approach is one of the most student-centred approaches amongst the integrative approaches mentioned in this review. In his criticism of traditionalist curricula, David Brown, a professor in Education, states that “traditional curricular delivery systems suffer from trying to present too many facts in a completely isolated

manner” (Brown, 2006, p. 778). He suggests that a Transdisciplinary approach to curriculum building, designed by students themselves and based on their own questions, would be a more effective way of learning and would better prepare them for their futures (Brown, 2006; Drake, 2012).

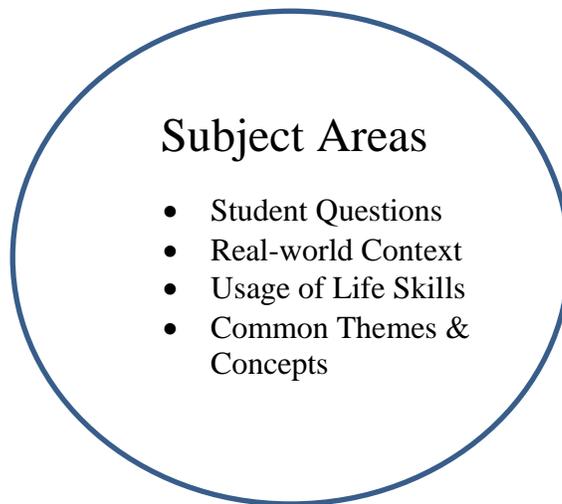


Figure 3 The Transdisciplinary Approach

This interdisciplinary approach is not new and was heavily endorsed by John Dewey over 70 years ago: “...the newer education contrasts sharply with procedures which start with facts and truths that are outside the range of experience of those taught, and which, therefore, have the problem of discovering ways and means of bringing them within experience” (Dewey, 1938, p. 73). The “newer education” Dewey refers to here is that of the experiential learning model, where tasks are designed to mimic and reinforce real-life applications of knowledge. Brady echoes the importance of this approach: “Any school that does not send its graduates off with a thorough understanding of the seamless,

systemic nature of knowledge — and the ability to use that understanding to live life more fully and intelligently — is failing” (Brady, 2004, p. 281).

2.3 Review of Subject Integration

In their study titled, *Integrating Mathematics, Science, and Technology: Effects on Students*, Hogaboam-Gray and Ross (1998) problematize the fact that very few studies on the effects of integration have been done despite the overwhelming endorsement of such programs. Other research supports this finding (Underhill, 1995; Hoachlander, 1999). The Hogaboam-Gray and Ross (1998) study revealed that when subjects are integrated, and material is delivered in a more organic way —i.e., they are not artificially separated into discreet subject streams—students experience higher motivation to learn and master a skill or engage with curricular content. This suggests that engagement can be increased through the application of interdisciplinary subject integration. Further, curriculum integration can help students perform better in school by focusing their attention on learning objectives that: span several subjects, and those objectives that are complimentary across subject areas (Hogaboam-Gray & Ross, 1998). Student performance and engagement are not the only factors that are considered when evaluating the efficacy of subject integration. The significant increase in inter-departmental cooperation between teachers when implementing interdisciplinary integration has been demonstrated to produce a much more collaborative learning environment in the school, benefiting both teachers and students (Hogaboam-Gray & Ross, 1998; Ross, 1998).

Hogaboam-Gray and Ross provide a counterpoint to their praise of integrated curriculum. As integrated programs often imply an increase in organizational complexity on the part of the teachers, and increased “cross-disciplinary conversations,” teachers can

“lose track of the structure of the disciplines” and their own “organization of ideas and principles” (Hogaboam-Gray & Ross, 1998, p. 1121). The increased interconnectedness of curriculum can also make it more difficult for students to make “vertical connections”—connecting lessons learned in earlier grades with those of senior grades—and can lead to “fragmentation” or an inability to make connections between previous and current learning (Hogaboam-Gray & Ross, 1998, p. 1121).

In Venville, Wallace, Rennie, and Malone’s (2000) research on bridging the boundaries of compartmentalized knowledge and student learning in an integrated environment, a gap in the literature is identified in the area of using mathematics and science in an integrated environment. Venville et al. (2000) found that student participants thought their learning and teachers’ teaching had been enhanced through the use of interdisciplinary techniques. Furthermore, teachers found that subject knowledge was less of a barrier to entry into interdisciplinary curricula for them in their teaching when they were allowed to “pool their skills” through the use of interdisciplinary integrative strategies (Venville et al., 2000, p. 35). This is an important finding as a common critique of integrating subjects has often been that it requires teachers with a broader knowledge base (Zolnierczyk, 2016). In the interdisciplinary environment, professional collaboration allows teachers’ knowledge to complement each other’s practice.

On their examination of the integration of academic and TE subject matter, Conroy and Walker (2000) explored interdisciplinary techniques in the secondary school environment within the aquaculture (the cultivation of aquatic animals or plants for food) classroom context. Their hope was that their model of study can be extended to other

subject areas (Conroy & Walker, 2000). They aimed specifically to: (a) establish frequency of integration of aquaculture with other subjects; (b) identify examples; (c) describe integration from both teacher and student perspective; and (d) identify implementation and successes (Conroy & Walker, 2000). These researchers found that aquaculture provided rich subject matter that could be easily adapted to any subject, e.g., cooking fish in hospitality classes, managing financial records in business class, generating promotional material in arts class (Conroy & Walker, 2000, p. 59).

While agriculturally-focused curricula are not as prominent in Ontario as they are where this study was conducted—the U.S.—this study serves to illustrate evaluative and observational techniques used in the field of research. A majority of teachers indicated that science, technology education, and mathematics (STEM) subject areas had significant potential for integration with aquaculture (Conroy & Walker, 2000). Interestingly, the teachers also felt that “a change from the traditional vocational emphasis resulted in more ability to develop [interdisciplinary] opportunities” (Conroy & Walker, 2000, p. 60). This “traditional” emphasis is a reference to vocational programs that focus exclusively on specific job training, rather than an attempt to build on and link to academic subject matter. This job training approach was standard in Ontario’s TE prior to the mid-1980’s (Smaller, 2003).

The aquaculture classroom context and the project-based learning approach in the Conroy and Walker (2000) study is a vessel not only for practical, job-related knowledge, but also as a means of focusing STEM subject-matter into digestible content for the students. This, in turn, results in students engaging in several subjects in a more focused and meaningful way than learning in discrete subject area courses; increases in student

achievement levels were also observed (Hogaboam-Gray & Ross, 1998). This study aligns with the focus on the mathematics and TE curriculum in my research. The findings also indicate that moving towards activities with a more integrative design—ones that approach multiple subjects within the same project—would allow for greater collaborative opportunities between academic and TE teachers.

Hill and Smith's (2005) work, well documented in *Research in Purpose and Value for the Study of Technology in Secondary Schools: A Theory of Authentic Learning*, explores the nature of learning academic and technology subject areas within the context of TE. In their study on problem-based learning, a strategy closely associated with teaching in TE, Hill and Smith (2005) use the philosophical framework of social constructivism. This framework is also echoed in Savery and Duffy's (1995) and Venville, Rennie, and Wallace's (2005) work on problem-based teaching approaches and student understanding of science in an integrated setting. Drawing on a constructivist conceptual underpinning of subject integration, the context of learning becomes just as important as the subject content itself and knowledge is built through social negotiation (Savery & Duffy, 1995; Driver, Asoko, Leach, Mortimer & Scott, 1994). Putting subject integration into this constructivist context can then refocus our view of learning and shift it from being more factual and content-based into a more "dynamic" experience—one that builds and uses knowledge with learners being collaboratively "engaged in problem solving and active inquiry" (Venville et al., 2005, p. 453).

2.4 The TechnoMath Program as Interdisciplinary Learning

The goal of the TechnoMath curriculum is to "create an engaging and relevant experience for students" in the delivery of the mathematics and TE curricula through an

integrated model (Ontario Ministry of Education, 2018, p. 1). The TechnoMath program observed in this study integrated grade 10 applied mathematics with grade 10 construction. These classes were consecutively scheduled in the first two periods of the school day. Mathematics and Technological Education teachers co-planned and in some cases co-delivered lessons that integrate subject content. Summative projects for the classes, while submitted to each individual class, included concepts and ideas from both the mathematics and construction class—e.g. measurement, Pythagorean theorem, slope and pitch, surface area and volume of insulated concrete forms, quadratics, etc.

The TechnoMath program is an example of Interdisciplinary subject integration. As the borders between Multidisciplinary and Interdisciplinary learning can sometimes be difficult to differentiate, I will elaborate on my categorization of TechnoMath's subject integration within the latter method of integration (Interdisciplinary), as opposed to the former. Within this type of integration, "the curriculum revolves around a common theme, issue, or problem, but interdisciplinary concepts or skills are emphasized across subject areas rather than within them" (Drake, 2012, p. 18). TechnoMath emphasizes the common theme of mathematical concepts across the two subject areas (mathematics and construction) to more explicitly connect themes and enduring understandings between the two subjects. For example, students at one point were asked to design a ramp for a community non-profit organization. In order to successfully execute the assignment, they had to use principles learned in their mathematics class and apply them in the construction class. In a Multidisciplinary approach, students are also "expected to make the connections among subject areas" themselves, and "content and assessment remain firmly within an intact subject," (Drake, 2012, p. 16) in the TechnoMath program,

teachers collaborate in order to co-design a curriculum that can explicitly present these connections to the students in order to facilitate their understanding—characteristics much more akin to an Interdisciplinary model. TechnoMath is referenced as creating “cross-curricular connections between TE and mathematics by co-delivering them ... using an integrated approach over two periods” (Ontario Ministry of Education, 2018, p. 1). The subject areas, while still separate in their respective periods, use and apply similar curricular concepts—mathematical in nature—across both periods. Government literature on the program does not specifically assign which approach to integration is taking place.

2.5 Teacher Collaboration

When thinking about subject integration, student achievement, while a very important component, is not the only concern or benefit to its use—collaboration can also be a natural by-product of subject integration: “For example, integration might increase cross-departmental conversations of teachers, thereby contributing to a collaborative school culture rather than a culture defined by norms of privacy and allegiances to home departments” (Hogaboam-Gray & Ross, 1998, p. 1120). The examination of teacher collaboration is of particular interest to this research as the TechnoMath program requires teachers to collaborate in planning their subject integration.

In the context of interdisciplinary integration and inter-departmental cooperation, positive social relationships amongst staff were viewed as critically important, based on the literature. In their systematic review of teacher collaboration, Vangrieken, Dochy, Raes, and Kyndt (2015) identified several terms associated with, and often conflated with, teacher collaboration: teacher teams, teacher collaboration, professional learning communities, teacher learning communities, and teacher learning teams. The variety of

terms and their inconsistent and interchangeable usage by teachers highlighted by the authors revealed “conceptual confusion,” making it difficult to define the various forms of collaboration that take place within the teaching profession (p. 23). For example, the term “teacher teams” was encountered in over 52 studies, yet very seldomly was the term “team” actually defined clearly (p. 23). In order to maintain consistency, working definitions of relevant terms relating to teacher collaboration for this review will be taken from Vangrieken et al.’s (2015) work. Collaboration and collegiality are the two main constructs primarily present in literature pertaining to teacher collaboration; however, there is an important distinction drawn between them in the literature. Collaboration is understood as the “joint interaction in the group in all activities that are needed to perform a shared task,” whereas collegiality is used as a term to identify the “quality of the relationships among staff members” (James, Dunning, Connolly, & Elliott, 2007; Kelchtermans, 2006; Vangrieken et al., 2015, p. 23). Collegiality is seen as a social and professional obligation between people that work together—it is based more around mutual sympathy and solidarity regarding work (Vangrieken et al., 2015). An important aspect of collaboration is its association with a “task-related focus, including working and reflecting together for job-related purposes” (Vangrieken et al., 2015, p. 23). The term ‘team’ is defined by Vangrieken et al. as “a collection of individuals who are interdependent in their tasks, who share responsibility for outcomes, who see themselves and who are seen by others as an intact social entity embedded in one or more larger social systems” (p. 25).

Another important aspect of collaboration is the degree to which it occurs between people—in our case, teachers. Vangrieken et al. (2015) cite a continuum of

collaboration that consists of five levels, moving from independent forms of collaboration all the way to highly interdependent forms. These five levels are: “storytelling and scanning for ideas, aid and assistance, sharing, joint work, and teamwork” (Vangrieken et al., 2015, p. 26). At the teamwork level, teachers are highly dependent on each other in their collaborative practice.

In their study of social practice among school professionals, Christophersen, Elstad, and Turmo (2011) surveyed 237 teachers in order to further explore the often-solitary nature of the teaching profession and the absence of “potentially positive synergies that can exist between teachers within the social organization of the school” (Christophersen et al., 2011, p. 640; O’Day, 2002). This reality is often in contrast with the collaborative expectations placed upon the teacher by administration and guiding policies. The study sought to answer the research question, “how social practice among teachers and school leaders in school communities is mobilised for sustained academic pressure in teaching practice?” (Christophersen et al., 2011, p. 640). The strongest correlation they found was the relationship between positive attitudes towards the school and its impact on teachers (Christophersen et al., 2011). Unsurprisingly, they found a connection between teacher-teacher trust and peer collaboration—the authors concluded that the trust between teachers and principals has more of an impact on teachers than what is present between the teachers themselves, pointing to teachers ascribing more weight to their relationship with administration rather than with their peers (Christophersen et al., 2011). This finding reinforces how solitary teaching can be and how difficult a barrier it is to overcome. This study further illustrated the complexity surrounding school social dynamics and how they influence teacher collaboration.

It is no surprise, however, that teachers who collaborate with one another are shown to be more effective in their work than those who do not (Spillane, Shirrell, & Adhikari, 2018). Spillane et al. (2018) reviewed five years of social network data from one school district to “explore the relationship between teacher performance and teachers’ instructional advice and information interactions” (p. 1). They found that higher performing teachers are more likely to seek out advice than they are to be sought after for it, providing further evidence that collaborative habits are associated with excellence in the teaching profession. Their research also shows that a school’s organizational factors play a significant role in teachers’ professional interactions. Specifically, Spillane, et al. (2018) found that teachers are more likely to interact with each other when they teach the same grade, while those who teach multiple grades are “less likely to seek and provide advice and information” (p. 3). This would indicate that teaching multiple grades, a common practice for high school teachers, creates barriers to collaborative practice.

In his comparative case study, *Teacher collaboration: Good for some, not good for others*, Johnson (2003) examined the outcomes of four Australian schools attempting to promote greater collaboration between teachers. He found several positive aspects of teacher collaboration. First, he found that teachers perceived an increase in moral support as a result of collaborative practices—they (the teachers) reported “important emotional and psychological benefits associated with working closely with colleagues in teams” (Johnson, 2003, p. 343). Teachers also experienced an increase in morale, resulting in lower staff absentee rates and a perceived reduction in negative stress levels. Teacher collaboration observed in this study also resulted in increased levels of “teacher talk” or the process of “personal and professional sharing or self-disclosure” (Johnson, 2003, p.

343). During these conversations, teachers had the opportunity to share issues pertaining to student welfare and their own professional practice, providing them with a space for emotional and professional support and growth through challenges experienced in their profession. Over 80% of participant teachers reported feeling part of a “learning community” which helped them engage in professional development opportunities as well as help in the “breaking down of traditional subject barriers which previously inhibited learning and sharing expertise across subjects” (Johnson, 2003, p. 344). Not all the consequences of teacher collaboration in this study were positive, however. Around 40% of teachers’ responses to Johnson’s questionnaires revealed that “the need to meet more frequently with colleagues to discuss and plan collaboratively placed an added work burden on teachers” (Johnson, 2003, p. 346). Moreover, teachers also reported a loss of autonomy as they felt “constrained” when working collaboratively (Johnson, 2003, p. 346). There were also some participants in the study that resisted the change brought about by collaborative efforts, thus leading to a reported increase in interpersonal conflict among participants. Finally, instances of factionalism were reported; these occurrences involved competition between teacher teams in which teams defended their established “norms . . . against the threat of other groups” (Johnson, 2003, p. 348). Though it is important to note that when this phenomenon (factionalism) did appear, it was in a school that had not embraced a “collaborative culture” (Johnson, 2003, p. 348). This finding emphasizes the importance of the whole school community buying into the idea of collaborative practice in order for it to be successful.

Zhou, Kim, and Kerekes (2011) explored instructors’ and pre-service teachers’ experiences in a collaboratively taught and integrated methods course in a university

setting. Although this research was not conducted in a secondary school setting, lessons learned from it can prove invaluable to the understanding of collaborative teaching practices. Researchers found that collaborative teaching was not only “feasible,” but also “beneficial to both instructors and pre-service teachers” (Zhou, Kim, & Kerekes, 2011, p. 123). The authors found, however, that there were also challenges associated with collaborative teaching practices—mainly, that it can be “time consuming because it requires more meeting time for planning, sharing, and discussion” (p. 134). They also found that collaborative teaching could be “confusing to students who are used to isolated teaching” (Zhou et al., 2011, p. 135). They did find that preempting the course with a “well organized” syllabus tended to somewhat alleviate the problem, however (p. 135). Overall, Zhou et al.’s study suggests that there are net positive results to teaching collaboratively.

In their scoping literature review on collaborative inquiry, DeLuca, Shulha, Luhanga, Shulha, Christou, and Klinger (2015) found that a greater “likelihood of success” is observed when teachers have “previously shared professional learning experiences” (DeLuca et al., 2015, p. 649). In programs such as TechnoMath, if these findings hold true, one can anticipate barriers in collaboration as these programs are usually comprised of teachers from completely different backgrounds—this, and how teachers overcame these barriers, were an area of focus during data collection. Another challenge experienced by teachers during collaborative inquiry practices observed by DeLuca et. al (2015) was temporal constraints. As noted in the scoping review: “It is the responsibility of teachers and school leaders to find adequate time through purposeful timetabling, fiscal resources and teacher coverage” (DeLuca et al., 2015, p. 654;

Robinson, 2010). Not only is time necessary in building effective professional relationships that lead to productive collaborative practices, but it is also necessary in establishing collegial trust (DeLuca et al., 2015). DeLuca et al. (2015) also explored the benefits of collaborative inquiry among teachers. Collaborative inquiry allows the space for teachers to “gain professional knowledge” and aids in professional development as well as the promotion of “educational improvement and change at both student and school levels” (DeLuca et al., 2015, p. 650).

2.6 Teacher Collaboration in the TechnoMath Program

In the TechnoMath program, teachers are expected to collaborate in order to facilitate student learning of interdisciplinary goals over two periods of class—a TE and mathematics class. Government documents state that the program’s content is being “co-delivered ... using an integrated approach over two periods,” it also includes anecdotal reports from the prior year’s piloting of TechnoMath in which teachers reported that there were “increased levels of engagement and relationship building ... increased collaboration between staff to co-plan and co-create learning activities and share experiences/expertise with content... and an increase in community engagement and collaboration” (Ontario Ministry of Education, 2018, p. 1-2). When teachers collaborate, they are also providing a positive model for students to follow in their own daily and future practice (Coke, 2005; Vangrieken, Dochy, Raes, & Kyndt, 2015). Interdisciplinary subject integration of academic and TE subject matter through teacher collaboration stands to greatly benefit students.

2.7 Technology and Mathematics Education

As TechnoMath involves integrating mathematics with the technology education curriculum in Ontario, it is also necessary to review, briefly the orientation to technology education and mathematics education in the province.

The last time there was substantial evaluation of TE by the Ontario Ministry of Education was when the Report for the Royal Commission on Learning—*For the Love of Learning*—was released (1995). This publication suggested the importance of creating an environment conducive to research in order to document student learning in the ever-changing educational environment. Leading up to this report, a consultation paper on TE was released by the Ministry of Education (1990). In it, language and motivation akin to the type used to justify the program being observed in this study—in 2018—are used: “In our own day, the technology of the sixties is not the technology required in the nineties and education has to be sure that remains relevant” (Ministry of Education, 1990, p. iii). The question of *future-proofing* our children has always been at the core of curriculum design. What the government was trying to do in the ‘90’s is not dissimilar to what current strategies being implemented now are attempting—to bridge gaps in knowledge through interdisciplinary integration, and to make learning more engaging, and therefore more effective. Similar barriers to academic and TE integration are present too— “The question is how to restructure the curriculum and the allocation of school time, so that the relevance of existing and emerging technologies is continually demonstrated to students” (Ministry of Education, 1990, pp. 11-12). The question of fair allocation of time spent teaching subjects has always helped dictate how curricula are built. From a research perspective, the practical benefit of an interdisciplinary approach is that more than one

discipline can be examined at a time. Considering the current TE curriculum was last revised in 2009, I believe that research in this field is indeed still relevant.

Not only has a firm grasp of mathematics been associated with professional success, it has also been linked as “one of the best predictors of later academic success and future career options” (Stokke, 2015, p. 2). In recent years, mathematics scores have been declining in most Canadian provinces, including Ontario. In her research paper, Stokke (2015) notes that this decline has been occurring since 2003 as measured by exams administered by the Organization for Economic Cooperation and Development (OECD). Ontario has also shown declines in mathematics scores via assessments administered by the Education Quality and Accountability Office (EQAO), while provincial reading scores increased, this suggests that “policies specific to mathematics contributed to the decline” (Stokke, 2015, p. 3). In her dissertation on whether or not mathematics and reading competencies integrated into career and technical education courses improve high school student assessment scores, Pierce (2013) states that a “general pattern” emerges from literature implying that “curriculum integration models featuring higher levels of connections between subjects may support more advanced construction and transfer of knowledge, and result in more pronounced advantages” (p. 132). Further, while the students in her quasi-experimental study testing “a contextual teaching and learning model for integrating reading and mathematics” did not show a statistical improvement in mathematics scores—though an increase in scores was observed—she found that learning mathematics “in context can facilitate the transfer of knowledge so that students are able to apply learning in new and unpredictable situations” (Pierce & Hernandez, 2015, p. 213; Pierce, 2013, p. 136). All of these

findings suggest that there is value in delivering mathematics curriculum using an integrated model.

2.8 Summary of Literature

Three main types of subject integration were explored in this literature review: multidisciplinary, interdisciplinary, and transdisciplinary. Multidisciplinary integration typically centres various subjects on a unifying theme through a variety of approaches. Interdisciplinary integration puts less focus on the individual disciplines—something which the multidisciplinary method does not—in favour of identifying the skills and knowledge in which they are rooted. The Transdisciplinary method of integrating curriculum is developed by the teacher and based around students’ questions and the driving principle behind it is to provide the learners with real-life context (Drake & Burns, 2004). According to ministry documentation, the TechnoMath program is an example of Interdisciplinary subject integration as “the curriculum revolves around a common theme, issue, or problem, but interdisciplinary concepts or skills are emphasized across subject areas rather than within them” (Drake, 2012, p. 18).

Positive social relationships amongst staff were viewed as critically important when discussing collaborative practice (Vangrieken et al., 2015). Collaboration and collegiality are the two main constructs primarily present in literature pertaining to teacher collaboration. Collaboration is understood as the “joint interaction in the group in all activities that are needed to perform a shared task” whereas collegiality is used as a term to identify the “quality of the relationships among staff members” (James, Dunning, Connolly, & Elliott, 2007; Kelchtermans, 2006; Vangrieken et al., 2015, p. 23). At the teamwork level, teachers are highly dependent on each other in their collaborative

practice. Collaborative inquiry allows the space for teachers to “gain professional knowledge” and aids in professional development as well as the promotion of “educational improvement and change at both student and school levels” (DeLuca et al., 2015, p. 650). In the TechnoMath program, teachers are expected to collaborate in order to facilitate student learning of interdisciplinary goals over two periods of class—a TE and mathematics class.

Integrative practices in curriculum have not only shown increases in student achievement, but also increases in inter-departmental collaboration between teachers (Hogaboam-Gray & Ross, 1998; Ross, 1998). Student participants in integrated curricula felt their learning and teachers’ teaching had been enhanced (Venville et al., 2000). Findings also indicate that moving towards activities with a more integrative design would allow for greater collaborative opportunities between academic and TE teachers (Hogaboam-Gray & Ross, 1998). Interdisciplinary subject integration of academic and TE subject matter through teacher collaboration stands to greatly benefit students.

Chapter 3

Methods

3.1 Research Design

This study was conducted through an exploratory case study (Baxter & Jack, 2008; Yin, 2003). Yin (2018) defines this method of case study as one that investigates a phenomenon within its real-world context—it is “an all-encompassing mode of inquiry” (p. 16). This methodology was chosen primarily because I wanted to explore a unique program implemented in two classes in one school in southeastern Ontario. An embedded single-case study—embedded because there are two separate classes in the single case—design was chosen over a multiple-case despite the presence of more than one class because they are all bound by the same TechnoMath program requirements (Yin, 2018).

The selection of the case study format of investigation was inspired and reinforced by its ubiquitous use in much of the literature reviewed (Venville, Rennie, & Wallace, 2005; Venville, Wallace, Rennie, & Malone, 2000; Sagardia, Bengoetxea, & Rodríguez, 2018; Hickman, & Kiss, 2010). A case study affords the ability to see “contextual conditions” in the classroom setting that I would not be able to observe using other methods (Baxter & Jack, 2008, p. 545). While some forms of case studies may require propositions in their preliminary construction, exploratory case studies—by virtue of their probing nature—do not typically begin with these; instead, the study is driven by its purpose (Yin, 2018). The purpose of this study being to examine how teachers in the TechnoMath program collaboratively applied integrated teaching within the program and how they navigated any challenges throughout its implementation.

Case studies, in establishing epistemological parity with the reader's understanding, help to bridge the gap between theory and practice, and ultimately encourage praxis. It is this epistemological "harmony with the reader's experience" that makes case studies a rich resource for learning and professional development (Stake, 1978, p. 73). I have always been partial to experiential learning—the case study methodology offers me the opportunity to observe as complete a picture of the TechnoMath program as possible and convey the experiences of the participants to the reader in a fashion that can facilitate vicarious learning. In short, it is my hope that readers, predominantly educators, will be able to more easily draw on lessons learned throughout the study of the TechnoMath program over the course of the 2018-2019 school year.

For this research, the boundaries of the case study were two classes in one high school in southeastern Ontario, during the first semester of 2018 (September- January), with two teacher participants.

3.2 Research Site and Participant Selection

The participants of this study were two teachers who were chosen because they were primarily involved in implementing the TechnoMath program in one school in a southeastern school board in Ontario. They—the teachers—implemented interdisciplinary teaching strategies between mathematics and TE classes. The mathematics curriculum was presented within the context of the broad-based technologies courses offered by the TE curriculum and the students would presumably be able to apply the learned mathematics concepts within their TE classes. One of the teacher participants was a mathematics teacher (MT) and one was a TE teacher (TT). The

mathematics teacher taught Grade 10 applied mathematics, and the TE teacher taught Grade 10 construction. These teachers, with guidance from the Ministry of Education and their school board in the form of program directives and board coordinators, have come together to design a course that implements components of the mathematics curriculum in a Grade 10 TE setting.

The two teachers were recruited once it was clear they were selected by their principal to implement the TechnoMath program. They first orally expressed interest in this study before the Summer of 2018 and were then formally recruited by email after school board and Queen's University ethics approval was granted. This recruitment approach was taken in order to determine if I had initial teacher interest to participate in the study. Teacher consent forms were given upon clearing ethics reviews.

The focus of this study is on the teachers' planning and implementation of the TechnoMath program. Two classes were observed. Across the two classes, there were the same 12 students. The students were not direct participants in the study, that is, no student data were collected. However, in observing the teaching and implementation process of the TechnoMath program, students were present. Following both Queen's University and the school board's ethics protocols, I provided the teachers with a letter of information to give to the parents to notify them of the research taking place in their classroom.

3.3 Data Collection

According to Patton (2015), when conducting case studies, all participant perspectives must be accounted for and observed as it is important to examine the realities and viewpoints of all stakeholders involved in the learning process. Teacher

perspectives were examined through five data types: participant-observation, teacher notes and documents relating to their collaborative exercises, any curricular artifacts generated throughout the program, field notes, and semi-structured interviews (Patton, 2015; Yin, 2018). These multiple data sources provided triangulated evidence for increased confidence in study findings (Patton, 2015). Triangulation occurred by using teacher notes, documents, and artifacts to corroborate and situate my own notes from observations and interviews.

3.3.1 Classroom, Planning Session, and TechnoMath Orientation Observations

Classroom and planning session observations took place over the course of the 2018 – 2019 school year during five separate visits to the school as well as one observation of a TechnoMath school board orientation session at the beginning of the 2018 Fall semester. This school board-hosted session was designed as an orientation for the teachers who were scheduled to participate in the TechnoMath program. The school participating in the program offered TechnoMath for only one semester—Fall 2018. Visits were centred around the beginning and end of the program to better contrast program development throughout its enactment. In order to increase richness of the case, observations documented classroom social dynamics, teacher actions in their classes, teacher relationships with their students, and with each other, as well as two teacher planning sessions conducted during the teachers’ preparation periods before class. Sensitizing concepts for field observations centred on the usage of integrated subject matter and the teachers’ negotiation of concepts presented that do not lie in their original curricular expertise, as well as their perceptions of students’ engagement (See Appendix A).

3.3.2 Artifacts

Curricular artifacts such as program documentation, assignment timelines, and teacher planning and assessment notes that exemplified their practice were also collected during interviews and observations. Having these multiple sources of program data and observations allowed for triangulation of data and therefore a more accurate representation of the program.

3.3.3 Interview Structure

A semi-structured interview format was chosen to allow for a more holistic perspective on participant experiences (Conroy & Walker, 2000). One-on-one interviews provided a means for participants to freely and anonymously share their thoughts, while a team interview allowed teachers to share their views with each other. One individual on-site interview was conducted with each teacher involved in the TechnoMath program along with one team interview. Interviews were conducted in January 2019 as the program was approaching its conclusion. The first two interviews with participants were individual interviews, followed by the team interview. This interview order was used to collect individual perspectives before holding the team interview—this allowed for formulation of team interview questions designed to explore points brought up during the individual interview phase. It also allowed participants to be more comfortable with the interview process as the interviews began on a smaller scale and led up to the team interview. All individual teacher and team interviews were audio recorded and transcribed in full and were approximately between 40 to 50 minutes in duration. Initial interview questions were centred around the research questions on program navigation, its barriers, and its perceived benefits (See Appendix B).

3.3.4 Confidentiality

Confidentiality was of primary concern, names and sites were anonymized to ensure protection of participants' identities. Due to the specific nature of the program design, it might be harder to conceal the identities of the teachers, this was discussed with them before asking for their consent in participating in the study. The pronoun "them" was used to refer to both teachers so as to increase anonymity of the participants. Confidentiality was also discussed in the Letter of Information and Consent Form the teachers were given.

3.4 Data Analysis and Representation

Due to the nature of qualitative study, data analysis and collection occurred concurrently (Baxter & Jack, 2008). The first step was to clean the data by taking an inventory of all data obtained and identifying any gaps that may be present (LeCompte, 2000). Transcribed individual interviews, team interviews, and observation data were inductively coded using NVivo 12 (Mac Edition) by analyzing them for emergent themes through close readings (Thomas, 2006; Patton, 2015). Artifacts including program documentation, assignment timelines, and teacher planning and assessment notes were used to exemplify emergent codes identified from the inductive analysis of interview and observational data. The goal of the inductive analysis was to link the research questions to the findings in the data (Guba & Lincoln, 1985; Thomas, 2006).

Themes were analysed within the context of the research questions and, the relationships that were formed, and the learning that was constructed as a group (the two teacher participants) throughout the observation period (Patton, 2015). Answers and anecdotes from each group or individual were identified using pseudonyms in order to

disaggregate data—MT for the mathematics teacher and TT for the TE teacher. Credibility and trustworthiness was increased by carefully documenting all procedures followed throughout the study (Yin, 2003). Involving my supervisor and committee member during this phase and asking for feedback throughout the process also helped maintain transparency and authenticity—that is, as true a representation of the observed case as possible—to the original case (Baxter & Jack, 2008).

The goal of data representation is to be as comprehensive as possible and to immerse the reader in rich, accessible detail, interpretation, and analysis (Baxter & Jack, 2008). Due to the complexity involved in the reporting of an embedded case, though it may only be a single one, it is vital to situate it in the appropriate contexts for thorough exploration—to accomplish this, I intended to use a thematic analysis in order to best represent emergent themes gleaned from observational data (Glesne, 2011). This approach allows the writer to situate and engage the reader in the proper context while also being able to convey the theoretical examination that a thematic representation affords (Glesne, 2011).

3.4.1 Emergent Codes

The initial coding yielded 70 codes. Following further readings, the combining of like-codes, and removal of repeat codes, I was left with 49 codes. Table 1 lists all codes generated and their frequency in order to show the relative presence of a code in the data. Bolded entries (i.e. Assessment, Challenges, Collaborative Practice, Curriculum, Definitions of TE, Student Learning, Subject Integration, and Professional experience) were used as headings to help categorize generated codes that were similar in nature. These headings were later used to help generate themes discussed in chapter 4. For

example, planning issues, structural issues, and TechnoMath challenges were all placed under the Challenges category as they related to challenges that were observed in during analysis. The Structural Issues code has 0 references as it served as a sub-category—sub-categories are underlined—for all the codes generated between the “administration” and “your own classroom space” codes.

Table 1 Code Frequency Table

Codes generated	References
Assessment	
Assessment	20
Challenges	
Challenges	2
<u>Planning issues</u>	56
Balance	5
Could've been better	4
Flexibility	9
Tech teacher specific issues	4
Time (merged into planning)	25
Uncertainty about the future	12
Unexecuted plan	4
<u>Structural issues</u>	0
Administration	13
Behaviour in different spaces	2
Department autonomy	8
Discord between admin and tech messaging to students	2
Financial	14
Guidance's role	7
Interdepartmental queries	4
Support structures	15
Supposed to be doing	7
Teacher expectation of the program	3
Usage of space	13
Your own classroom space	7
<u>TechnoMath challenges</u>	22
Overworked	10
Collaborative Practice	
Collaborative practice	39
Comfort level	5
Discussion of partner's role	16
Unfamiliarity with subject matter	4

Curriculum	
Curriculum	11
Backwards design	4
Difference between	9
Explicit mathematics mentions	14
Improvisation	6
Learning by doing	5
Mathematics driven	3
Problem solving	3
Tech driven	10
Definitions of TE	
Definitions of TE	4
TechnoMath definition	10
Student Learning	
Student learning	1
Learner autonomy	3
Student behaviour	17
Student engagement	16
Student reactions	5
Student experience	14
Transferable skills	6
Subject Integration	
Subject integration	10
Professional Experience	
Professional experience	25

3.4.2 Emergent Themes

After coding of the data and the removal and collapsing of duplicate codes, seven themes revealed themselves as suitable terms for the 49 codes. These themes were derived from codes that were similar to each other in content. As an example, the theme of Curricular content was derived from 8 codes relating to curricular content, design, and execution: Backwards design, difference between, explicit mathematics mentions, improvisation, learning by doing, mathematics driven, problem solving, and tech driven. The themes generated were: (1) Teachers' readiness; (2) Assessment; (3) Student

experience and learning; (4) Subject integration; (5) Curricular content; (6) Collaborative practice; and, (7) Financial and planning challenges. This chapter explores these themes and their codes drawing directly on participant data.

3.5 Reflexivity, Triangulation, Validity, and Limitations

Having multiple data sources is an essential strategy in increasing data credibility and ensuring proper triangulation of the data (Baxter & Jack, 2008; Yin, 2003; Yin, 2018). In collecting as wide a variety of data as possible, it is my hope to increase data credibility. Member checks and audience reviews were used at various stages to increase credibility of results (Mathison, 1988; Thomas, 2006). This included checking with participants after initial transcription of the interviews, allowing them to amend or add to their answers—this was done by emailing transcripts of interviews to participants and allowing them time to respond before starting inductive analysis. I ensured that they did not leave out any information by allowing multiple opportunities for contribution throughout the study (Mathison, 1988; Thomas, 2006). Member checking is an integral part of ensuring trustworthiness in case study research (Guba & Lincoln, 1989). Of import to note is Mathison's (1988) alternative view on the interpretation of inconsistencies and contradictions in triangulation data—rather than disqualifying results if they did not align, one must analyse why that occurred, learn from them, and attempt to situate them within the study. A thorough “subjectivity audit” of myself throughout observation and research was also necessary to maintain an awareness of my own subjectivity and bias, and how it may influence my reporting (Peshkin, 1988). Peshkin (1988) also suggests taking notes whenever emotional affects are noticed during research; these can be referred to later on and help situate observations within the context of

personal feelings. Therefore, I kept a reflexive journal, which was used to reflect on my positionality in relation to data collection and analysis. These journal entries were used to help guide and situate my thinking during data analysis. I focused on my emerging thinking throughout data collection and analysis and aimed to ensure that my analytic decisions were data-based.

The nature of qualitative study, while sometimes sacrificing generalizability, makes up for it by providing the reader with rich detail on real people, their experiences, and their struggles. Bassey (1981) writes that pedagogic research need not be generalizable to be of use to teaching practitioners. Rather, its utility is demonstrated by how teachers can relate it to their own practice. Another common concern with case studies is lack of rigor due to the complexity of cases in general (Yin, 2003). I hope to have addressed this potential critique by having multiple data sources in this study and engaged in data triangulation (Mathison, 1988).

Chapter 4

Results

4.1 Introduction

The seven themes were: (1) Teachers' readiness; (2) Assessment; (3) Student experience and learning; (4) Subject integration; (5) Curricular content; (6) Collaborative practice: and, (7) Financial and planning challenges. This chapter explores these themes and the codes which they represent, drawing directly on participant data.

The two teachers I observed were new to the TechnoMath program. Prior to their 2018 summer vacation, they did not know they were going to teach TechnoMath—they found out in June 2018. Though the teachers had resources to draw on from in their prior experiences teaching their respective subjects, they had little familiarity collaborating with teachers in other subjects, particularly in departments as physically distant (in terms of their location within the participating school) as mathematics and TE.

4.2 Teacher's Readiness to Implement TechnoMath

The first theme extracted from the data plays a foundational role in the subsequent six. It represents teachers' recognition that their personal and professional experience shaped their capacity to implement the integrated program. It also offers insight into what teachers believed the TechnoMath program was, in their own words, before beginning their collaboration. As such, we begin with how the teachers described their experience both in their prior roles as mathematics and technological educators, as teachers within the TechnoMath Integrated program, as well as how they understood the TechnoMath program itself.

4.2.1 Teacher Experience

The two teachers began their interviews by describing their past teaching experience in their respective fields of education. The mathematics teacher (MT) would be considered the more senior teacher of the two—they have over 15 years of teaching experience. They had only taught in an integrated setting once before when they were teaching science and mathematics courses, although that was years ago. In terms of the MT's familiarity with the TE space, they “know a little about tech” and have “used all of the equipment” present in the shop, which seemingly made the TechnoMath program “a good fit” for them. When asked about co-teaching in the same class with other teachers, the MT expressed that they were typically used to working by themselves and would rather “be in my own room with the door shut” than being observed by their peers while teaching. The MT was also fond of using technology in their classroom including a smart board, iPads, and cloud-based applications such as Google Classroom. They also expressed interest in re-using some activities and projects conducted during the TechnoMath project, showing an openness to new pedagogical styles and connecting their discipline to others.

The technology teacher (TT) had been teaching for four years—this includes teaching experience both TE and social science courses. As a technological educator, they had a prior job in a trade then went back to university to obtain their teaching credentials. While they were newer to teaching, they had past professional experience in other fields. There were instances where the TT commented on their own experience and how they did not “have their teaching practice figured out”—this contributed to challenges throughout the program which will be explored in one of the subsequent

theme-sections. The TT's initial goal in their professional practice was to teach social sciences, though they fell into TE because of a job opening and greater scarcity of teachers in that discipline. Despite this, they were enthusiastic about figuring out a way to make their construction teaching practice enjoyable and effective, and to provide the students with "something that [they] don't otherwise have in other classes." They displayed an openness to working with other teachers in programs such as TechnoMath, but, like the MT, they also appreciated having a space to themselves: "it's nice to have your own room that you don't share with anybody else, that you can set up the way you want;" they reinforced that "teachers really like that," referring to the ability to curate and maintain one's own space, without the worry of having someone else—another teacher—come in and change it. It was clear that both teachers appreciated working with others when it came to curriculum design and lesson planning, though, when it came to the actual teaching and usage of classroom space, they preferred to do it alone.

4.2.2 TechnoMath

From observations of the board orientation of the TechnoMath program held prior to the beginning of the 2018 school year, it was clear that one of the main goals of the program was to have students "arrive at the answers in multiple ways" during curriculum implementation, as was stated during the orientation. It was this perspective, along with one of ensuring that the program did not "make two islands," but "stay[ed] integrated," that guided the TechnoMath orientation. These guiding statements made during the orientation were intended to steer the teachers in their implantation of TechnoMath—to help them ensure that they keep integration in mind throughout its implementation.

After having taught the TechnoMath program for three months, the TT described the content of the program as “largely the same as what we’re doing in my other classes, the difference ... is what we’re focusing on, and how we’re approaching it ... because we really want to be able to use mathematics, because that’s kind of the whole focus.” Along with this focus on mathematics, the scale of the class projects conducted during the TechnoMath program—in curricular scope, timeframe, and materials—were larger than the TT was previously accustomed to: “the scale of some of the things was quite large.” This sentiment was echoed by the MT in a separate interview indicating that “some things haven’t changed” when referring to the style of teaching taking place in TechnoMath as compared to their previous teaching experience, though the MT indicated that the “focus is different.” The MT defined this different focus as starting with the problem, “and then fill in the mathematics to help the problem,” a description very similar to that of backwards design—an approach to designing curriculum in which one works backwards from “Identify[ing] desired results ... determin[ing] acceptable evidence ... [to] plan[ning] learning experiences and instruction” (Wiggins & McTighe, 1998, p. 3). The MT indicated that they had used backwards design in their own mathematics teaching in the past, but “it would be a smaller scale” as well—referring to the size of the projects they had used it on.

4.3 Assessment

Assessment emerged as a code 20 times and was thus assigned its own theme due to its high occurrence during analysis. The main issues that arose around assessment in the data were around differences in assessment approaches between mathematics and

technology courses, as well as how assessment practices changed between collaborative and non-collaborative situations.

Assessment was one of the first factors identified when participants were asked about key differences between teaching a technology course versus teaching mathematics. “Assessment has got to be one” was an immediate reply by the MT when asked to consider these differences and challenges. The TT agreed that in their experience, assessing in TE was very different than when they were teaching in the social sciences:

Our units are basically these series of projects we’re going to do. So, I try to take the expectations that we’re supposed to be learning and feed them into the project we’re going to be doing and, ideally, the project lends itself to that. But, in terms of when I go to assess it, it’s really hard to assess A1 and then A2 and stuff, it’s a lot more stuck together, so that, I think it’s different. At least in my time teaching outside of tech, it was more like ‘oh I have this expectation I got to do, so on this assignment, this is that specific expectation.’

It appeared that both teachers agreed that when assessing in the TechnoMath or TE environment, it became difficult to differentiate assessment streams, individual criteria within rubrics, and course schema from basing assessment on their final product at the end of a project—something which you’re “not really supposed to be doing” according to the TT (assessment should mostly come from observing the learning process and not the product itself). They also mentioned their lack of experience in assessment and that they’re “trying to figure out [their] way through it.” The TT indicated the informal nature of assessment often used in the TE space when they described the answers, they received from asking peers with more experience as “not something you’d say in a job interview”—indicating that they were aware that assessment methods used in the space

did not always align with ministry expectations. The MT also shared their difficulty in the assessment process in this regard: “a lot of my assessment is observation and what I think sometimes what I know they can do is not what they show me they can do, and it’s my professional judgment factor the comes in there sometimes.” Through these insights during the interviews, one can see both the difficulty involved in assessment of projects during the TechnoMath program, and how the teachers’ professional experience places them on different areas of the learning curve vis-à-vis their established assessment routines.

Assessment within the technological space, specifically, also presented safety and logistical challenges: “Especially in tech ... it’s not like you can sit and assess this one group that’s working, because you’ve got these other four groups that are working which you can’t really ignore.” This statement, made by the MT in the context of assessing in the tech space referred to how spread out the teacher’s attention has to be in order to safely monitor the whole class during the usage of power tools and other equipment, which can pose safety risks to the students. The TT also expressed frustration when describing expected assessment standards versus enacted ones:

It’s tough, it’s a lot grayer, I guess, because with us, it’s a physical thing. When you’re done with us, I really don’t want to just park that, but that’s what I end up marking. What I want to mark is how’d you approach the problem, how’d you think about it, if you encountered problems how’d you come around to it. But they take so long, it’s hard to document all that stuff all the way through.

It was evident that there was difficulty in adhering to administrative and curricular expectations of assessment; that is, the assessment of the process involved in producing

the product, not just the product itself. It appeared that this was not only because the TT was teaching a new program, but they were also overwhelmed with the amount of data required to be collected in an environment where one is always concerned with student safety in a loud and dangerous environment. These were unique considerations to the technological space.

Assessment presented interesting challenges within this program as students were still technically being assessed for two separate courses: mathematics and construction technology. The thought of giving a combined grade had come up during interviews but was seen as impossible by the teachers as they still had to give their students marks within each of the individual disciplines (i. e. mathematics and construction technology).

The TT elaborated:

Unless you were doing the whole thing yourself, I don't know how you'd give them one mark for both [courses] ... because there are some kids who are more engaged with written work, like sitting and doing math, there are other students who are more engaged with getting up and cutting stuff. You couldn't just give them one [mark]. Which people had talked about having projects and culminating [tasks] that were together, but we never got to that point and I think that would be really challenging to figure out. How would you even approach marking something like that?

The sharing of student information between teachers was seen as an advantage by both the MT and the TT while conducting TechnoMath. The MT mentioned that “the bigger the picture, the better” as far as assessment was concerned when citing that any extra information helped in student assessment—including, for example, sharing strategies that worked with a student who was struggling with class material or just with teenage life in general. It also served to reassure the other teacher that some class issues

that arose were not exclusive to that teacher: “I go to the TT and say, ‘I saw so and so do this thing.’ Ok, great, so it’s not just in my class.” This kind of feedback provided crucial support for teachers during an, at times, difficult year in which they were engaging with new material and methods of delivery. It also provided teachers with a more holistic perspective on students. Although, in the end, each student was still given a separate mark for each class.

4.4 Student Experience and Learning

Student learning was the theme assigned to a group of codes that centred around the teachers’ perspectives on students’ experience and outcomes of the TechnoMath program. The specific codes generated were: learner autonomy, student expectations, transferable skills, student experience, student engagement, student reactions, and student behaviour. After further analysis and removal of redundant citations, the theme was broken down into the following three categories: engagement, student experience, and transferable skills.

4.4.1 Engagement

Issues surrounding engagement often arose during interviews. The MT found that one of the hardest parts of executing the TechnoMath program was maintaining a “constant engagement factor...how do you keep that going for five months?” The participating teachers both agreed that conversations around engagement “came up all the time in discussion” during planning time.

Both the MT and TT reported that students' levels of engagement and motivation were not at the levels that they expected them to be. The MT cited their in-class experience:

I was surprised that, in here—the math class—the engagement wasn't what I thought it was going to be. I thought they were going to appreciate the tech side influence more than I saw. It was there, but it wasn't what I thought it was going to be. I thought it was going to be better, but not what I expected.

Despite this difference between expectation and reality of student engagement, the MT also specified that only about half of their class fell into this category: "There are half, maybe, of the class that I would say are very much more engaged ... they've definitely made a huge connection between the tech and the math, and they are very engaged in both."

The TT echoed this observation: "There was less motivation in my class than I thought there was going to be." Both teachers found this surprising as they expected more motivation and engagement because of the more applied nature of the TechnoMath program. They partially attributed it to the specific group of students participating in the program citing that there was "headbutting" between groups of students within the class and that grade 10 is also "the most tumultuous year of any of them." The TT also expressed frustration and found it to be a "struggle" with the fact that some students in the class did not want to engage with any of the hand or power tools: "Why are you in tech class if you don't want to use the tools?" Citing that more often than not, "The behaviour wasn't an issue, it was the motivation that was the issue." The TT expressed frustration with the fact that perhaps these students had not chosen themselves to be participants in the TechnoMath program, but were only there because it "was the only

math class of its kind [that] semester, so if you were enrolled in this level of math class this semester, you're taking construction." This raised administrative issues, which will be explored further in a later section in this chapter.

4.4.2 Student Experience

Both teachers were very clear throughout their observed teaching sessions and interviews that their main goal throughout the TechnoMath program was to provide as much of a positive and effective learning experience as possible. They expressed what this looked like during their interviews.

The MT's goal could be distilled to having the students not "memorize how to do something.... that they [be] thinkers" and that they are able to "attack [a] fairly open kind of question" when confronted with it. The problem-solving methods that the MT was actively avoiding was a rote learning style of problem solving, or, as they put it: "step one, I do this, step two, I do this, step three, I do this, etc." The MT believes that, through TechnoMath, students' experience has resulted in "more ingrained learning," and that, in a mathematics setting, whenever the students can "visualize or put their hand on" a mathematical concept, it has more "lasting value than straight-up theoretical"—i. e. instruction with little practical application of concepts—styles of teaching. The MT believed that deeper learning would be achieved through experiential teaching practices—practices which were present in the TechnoMath setting. The TT also wanted learners to have "a good experience [in class] but still learn."

During observations, I noted that the learning environment was indeed more casual than an exclusively teacher-centred class in its atmosphere. The class was often working in groups and there was seldom time spent facing the front of the class or

observing the teacher lecturing—though this was present at times, more so in the mathematics portion of the program than the construction technology section. These occasions where the teacher presented necessary underlying concepts were certainly outweighed by time spent applying the concepts to building catapults that fired a tennis ball projectile, for example, and then recording the ball’s flight path with iPads using mathematical software such as Desmos to translate the flight path into a quadratic equation.

The kind of experiential learning that resulted from lessons such as the catapult and quadratics lesson was described by the MT as being a “more ingrained” type of learning. They refer to it as “deeper learning” that students have an easier time retaining, as opposed to more surface level, less exploratory learning which the students may immediately forget the next day—or, as the MT puts it: “tomorrow I’m not going to have any idea what you were just talking about today.” The MT elaborated: “Anything that they can visualize or put their hands on has far deeper, lasting value than straight-up theoretical.”

The TT echoed this sentiment in their individual interview stating that TechnoMath allowed them to “do things in theory that, we wouldn’t otherwise be able to do, or that would be maybe a little too complicated.” Here, the TT was specifically referring to the fact that they were able to delve deeper into the mathematics of construction because of the support of the MT and the parallel mathematics curriculum co-occurring with construction during TechnoMath. I will elaborate on the relationship between the teachers themselves later on in this analysis, but the benefits of this collaborative practice deserved mentioning here as this relationship benefitted student

learning throughout the program. According to the TT's following description of what they were able to do during the TechnoMath program, a part of these benefits was a further in-depth examination of mathematical concepts in the TE space, exploration that would not have been possible outside of the TechnoMath program:

So, for example, calculating angles, we didn't have the students in my class do it very much, but it requires trigonometry—I can figure out how to do it, but I don't know it well enough to be able to teach it to the kids . . . they're going to calculate volume or something like that of the ramps that we're building, like that's not something I would ever be able to do effectively [on my own].

Before programs like TechnoMath, when the TT was faced with a challenge like this, they would “do the heavy lifting” on the complicated mathematics, instead of taking time out of an already full schedule to attempt to teach the concepts.

4.4.3 Transferable Skills

The teachers emphasized many of the skills being taught in TechnoMath were transferable across contexts. This idea was reinforced in the board training session where the MT—when referring to the style of teaching that they were striving for in the coming academic year—highlighted that they wanted “students to arrive at answers in multiple ways,” and that the application of mathematics to construction technology would strengthen this type of mindset.

The MT described using mathematics skills in the context of construction technology as having “something to put [their] hat on.” They elaborated: “It's to have that scope, that ‘this is real math, this really does matter, and this is why—because you're building these things and you're designing these things and you can't do these things without the math behind them.” They described TechnoMath as being “a really good fit

for that mindset.” This viewpoint emphasized the practical nature of the program in that it uses construction technology as a real-world anchor for theoretical mathematics concepts and theorems—the learners actively see the application of the mathematics they are introduced to within a class period, sometimes in the same period itself. The TT echoed this viewpoint of skill transferability: “We’re not training carpenters, or plumbers or electricians, we’re giving them basic transferable skills.” Deep down, the construction technology course is “applied science and math” according to the TT—the students are “taking those real concrete things and we’re putting them to real use, and you have to know a bunch of these [mathematical] concepts in order for it to work.” Upon analysis of these perspectives, given in each of the participant’s individual interviews, it was clear that both teachers agreed when it came to the rationale behind content being taught in TechnoMath: they were delivering a mathematics curriculum anchored in the real-world application of construction technology—one which facilitated the transfer of mathematical principles to projects in the construction technology class.

4.5 Subject Integration

As a code, subject integration was found ten times in observational and interview data. Due to its relatively high frequency during the analysis stages, this code was made into its own theme and will be discussed in the following section.

The nature of subject integration in TechnoMath was primarily centred around the facilitation of teaching mathematics by using construction technology as a vehicle to illustrate concepts in experiential and visual ways. This presented opportunities for inventive lessons that were mostly viewed as successful by the teachers. The MT enjoyed the catapult lesson so much that they plan to use it in their mathematics class even after

the TechnoMath program concluded. “The catapult thing was super cool. And maybe if I taught the [grade 10 mathematics] again, maybe I would go borrow catapults from tech and do it again that way, because I think that was very effective that way.” There was also another instance in the mathematics class where the MT had the class conduct a warm-up linear systems exercise in which they had to figure out and cost how many board feet of wood was required for a particular building project and which store offered the most cost effective solution—the students were engaged in the activity. These examples served to illustrate the lasting effects that can occur on teachers’ planning and teaching efforts when subject integration is used—the introduction of a teaching material (a product of construction technology: the catapult) to a teacher that would not have otherwise encountered it had they not interacted with a subject outside of their own (construction technology).

Subject integration provided the added advantage of offering students a variety of subjects and contexts within the same program. This subject integration also offered a level of differentiated learning and opportunities for engaged students to display where their interests or attitudes may have been— “There are some kids who are more engaged with written work, like sitting and doing math, there are other students who are more engaged with getting up and cutting stuff.” Students naturally have exposure to different subjects throughout their school year in the form of individual classes. The difference in TechnoMath is that they are being assessed in two different subjects by teachers who are delivering an integrated curriculum, this not only offers a more holistic view of assessment for the teachers in the form of observations that the teachers share with each

other on students' projects, but also an opportunity for learners to more easily link concepts between two separate subjects as their projects often integrate into both classes.

4.6 Curricular Content

The curricular content theme was derived from the clustering of eight codes from the data with a combined total of 65 occurrences in the data. These codes were: mathematics driven, tech driven, problem solving, backwards design, learning by doing, improvisation, differences between, and explicit mathematics mentions.

The goal of TechnoMath was to highlight the connections between the mathematics and construction technology curricula in order to engage students and have them be able to more easily identify the links between mathematics skills and their application in construction technology. All grade 10 students taking applied mathematics in this semester were required to participate in this program. As the TT stated: "If you're in grade 10 applied math class or you're in my grade 10 construction, you have to be in both." Along with this, grade 10 mathematics is a mandatory subject while construction technology is not—this can lead one to assume that, ultimately, one of the TechnoMath program's main goals was to ensure that students learn and acquire a deeper understanding of mathematics skills as facilitated by its application in the context of construction. The TT affirmed these beliefs when they said, "we really want to be able to use math, because that's kind of the whole focus." I mention this here as it was important to establish what guided the production of curricular content in this program—was it the mathematics that informed the construction content, vice versa, or were they mutually beneficial?

When referring to this curricular hierarchy within the program during interviews, the TT stated “we (the tech section) could do whatever we want and [the MT] would figure out a way to make the math work.” For example, the TT mentioned how trigonometry had “a lot of different applications,” thus giving them “free reign to do what I want, and the tech project drove the course.” The MT mirrored this sentiment in their interview:

And so, once that project was determined, then it was my role for me to figure out ‘well, what curriculum can I make fit that project? ... so, once the projects were there, I have to hunt and peck and see which parts, which expectations can be met with this project.’

With the exception of the catapults lesson—which, according to the TT, were “driven largely because they (the MT and students) needed to do quadratics”—the rest of the curricular content was “driven by this course (construction technology)” and “everything that [they] did was planned around projects.” This was partly due to the often complicated logistics surrounding the organization of an activity in the construction class. It would follow that extracting contextually related mathematical principles from an already planned construction activity would be the path of least resistance when designing curriculum for TechnoMath. This would often require that the MT “be flexible with the order of the curriculum” as sometimes materials necessary for construction projects were not ready for the activity to proceed in time.

The TechnoMath teachers followed principles of backwards design when designing and planning curriculum for the class. The TT described their thinking process: “this is what we’re making, this is how much we need, this is what we need them to come to.” The backwards design process begins with first arriving at what the end product will

be (what we're making), establishing the materials required for the project (this is how much we need), determining the enduring mathematics and technology lessons that will be embedded in the activity (what we need them to come to) and, finally, developing assessment strategies for the class. This strategy in curriculum design is not dissimilar to what is used by many TE teachers. It is a design philosophy that fits well here as there are budgetary constraints and materials that must be purchased prior to beginning an activity—knowing what the final product is made it much easier to establish costs, purchase materials, and, ultimately, see if the project was affordable for the teachers and school vis-à-vis time and money considerations.

Curricular design in TechnoMath demanded flexibility and sometimes, improvisation. According to the MT, due to the logistical complexity of some of the projects in the TechnoMath program—building garden planters for the school, accessibility ramps for local businesses, and catapults that can launch tennis balls to explore quadratics—there would sometimes be delays because “materials don't get delivered when they are supposed to.” This required the teachers to develop flexibility in their curriculum throughout the program; as the MT put it: “Yep, it's not happening today, so we're going to do this instead.” Sometimes this meant that the teachers themselves were required to pick up the materials on the weekend: “We had to go and pick stuff up ourselves to do the garden boxes.” This also required that teachers had to be flexible enough to have other activities ready to go to replace the delayed projects, as the MT put it: “this project isn't going to get started now, so maybe we have to find something else instead. So, that ‘go with the flow’ kind of ‘real world happens.’” The TT used a “place holder” activity of building shelves with the students when the originally

planned activity was delayed due to lack of availability of materials and guidance from the company that was contracting out the work. This shelving activity ended up taking “way longer than it was supposed to” resulting in a “squeez[ing] [of] the other projects.” This was one example of how a single planned activity in the context of TechnoMath or construction technology can throw off a significant portion of teaching time if supplies are not available or participating third parties are not on the same timeline as the teachers.

The most successful project according to the teachers was the garden planter project, as the TT stated:

Our garden planter project was probably the best one we did, and it was the most integrated, they need more projects like that and less projects where it’s just like I’m doing something and then we tack the math on in some creative way. That was integral. We actually had the design and could’ve just built it, but we made them go through the whole process of designing it and figuring it out, so more projects like that. . . . They had to calculate volume, surface area, conversions from board foot to linear foot, estimating things like that. Measuring, layout, how are things going to be laid out. It was the most complete project that I did this year.

In fact, the teachers went so far as to say that “nothing was as good as that afterwards because it was really integrated, a lot of the stuff that they did in math, we took and directly used. We got to go out and install them. The kids bought in a little more.” The success surrounding this project seemed to lie in the fact that the mathematics was organically integrated into the production of the construction component, the project itself was scaffolded by the mathematics in digestible increments, and there was enough time prior to the project for detailed planning of its proper execution.

4.7 Collaborative Practice and Challenges

Collaborative practice and challenges as a code was cited 39 times, due to this high frequency found during analysis, it was deemed fit to be classified as its own theme. Unfamiliarity with subject matter, comfort level, and discussion of partner's role were the three other codes that mapped onto collaborative practice.

Collaborative practice played a key role in the successful implementation of the TechnoMath program. Throughout the semester, both teachers engaged with each other in order to overcome challenges, design curriculum, and become better teachers for their learners. Collaboration in this program began with the board training session prior to the start of the semester. This session served as an orientation for all of the potential schools participating in the TechnoMath program that year (only the observed school ended up actually implementing the program in the board). From the onset of the session, it was clear that its organizers focused on laying the foundation for teamwork by having the participating teachers work with each other in cooperative exercises that encouraged collaboration in designing activities centred around mathematics and TE curricula. Later in the semester, during observations of the TechnoMath planning sessions held by the study participants, examples of collaboration were evident.

During the first observed planning session, the teachers were trying to figure out how to implement an activity suggested to them by the board. The activity centred around building accessibility ramps for a community non-profit organization. There was a moment where the MT asked the TT for clarification about the project worksheet they were looking at as it centred heavily on woodworking and construction design, the TT had a look at it and was also puzzled by the suggested explanation of how to go about

building the ramps. They both looked at the online calculator app provided by the organization, but it was not working, nor did it offer underlying explanations for why the instructions were the way they were—the teachers were still looking for answers and had come together to begin brainstorming possible explanations. At this point, the MT began running manual calculations on the worksheet while the TT wrote an email to the organization to try and get some answers. This was all in an effort to better understand the activity so that they may more easily integrate the mathematical foundations so as to better deliver the lesson for the class. After writing the email, the TT returned to the worksheet and discovered the rationale behind the measurements given using their prior woodworking knowledge. This helped the MT verify that the numbers were indeed correct and that the reason that they could not make sense of the worksheet to begin with was that the units being used were in radians and were not labelled as such—the teachers thought they were in degrees. They then proceeded to discuss the mathematics required to be taught (trigonometry, in this case) in order to properly support the building of the ramps, appropriate classroom grouping patterns, potential classroom management issues given their prior observations in class, and the scheduling of the project itself—all components of a recipe for an effective lesson. This was a small example of the symbiotic nature of the collaboration that occurred during the planning sessions—without it, the teachers would not have been able to structure the TechnoMath program as quickly or as efficiently as they did. The teachers relied upon each other for their lessons to work; usually, the MT’s mathematics lesson was required in order for the students to understand and get the most out of the TT’s construction class. The expertise of both of the teachers

was often required to navigate the potential challenges projects and curriculum design of the program.

Throughout the TechnoMath program, the teachers remained in constant contact. The MT stated that they felt lucky to be in such a situation: “I think we’re lucky that we see each other all the time, and we kind of, you know, touch base on the fly, like ‘where are you at, what’s happening next?’” A high frequency of contact, communication, and planning meetings was necessary as proper timing of both the mathematics and construction classes was required to properly run the program, and the most complicated aspect of the planning to figure out. The MT points this out in one of their interview responses:

The getting together for the big things, like planning the culminating activity and what project order should we be doing and how do these things fit together, and a lot of timing. Timing was the big thing. I can plan my curriculum around the projects, and how [they] plan [their] projects, but the timing of how to make everything mesh together was the part that we would need some time to figure out.

There was sufficient money to enable the teachers to request supply teachers and take administrative time to plan, though there were other considerations that made this less than appealing for the teachers to do very often—these considerations will be discussed in the following section, Financial and Planning challenges.

The TT reinforced the importance of collaborating with others in this type of program as they stated that they would participate in this program again if given the opportunity. They mentioned how “it’s better to collaborate with somebody else” and that having a partner provided one with valuable resources such as “the things that you need them to know that could be done in their curriculum at another time by someone who

knows it better.” This spoke to collaborative teaching as providing a division in labour so that more time can be spent with hands-on building—in the case of construction technology—and less time on pre-teaching mathematical concepts, for example. This was elaborated upon by the TT:

So, If I need a circle that is 36” in diameter, you’d need to know what a radius is and how to figure it out so you could make a jig and that kind of stuff. If you had to build these benches, how much wood is it? That’s where if I’m on my own, I basically hand it to them and say this is how you do it, it’s not really figuring it out.

This idea reinforced the added value of collaborative planning in TechnoMath. Had the TT not had the support of the MT to scaffold student learning of the underlying mathematical concepts of building the benches previously mentioned, the TT would have skipped over it as they would not have had enough time to cover both the theory and the building of the bench. In the context of TechnoMath, students had the opportunity to engage with and practice the theoretical mathematics that was presented to them in a meaningful and experiential way.

4.7.1 Collaborative Challenges

This subsection of the collaborative practices theme was created to differentiate between the practices and the challenges of the collaborative experience in the TechnoMath program. It focuses on collaborative challenges experienced by the teachers.

Despite this high level of consultation and collaboration with each other, the TT still identified the physical differences and separation between the two classes: “I think that we still kind of operate separately, if that makes sense, like it’s not as cohesive perhaps as it could be in the sense that there is mathematics class and there is tech class,

we talk about some similar things but they are still effectively two separate classes and I don't really know how you fix that." This raised the logistical issues of collaboration between two very different classes—one was more scholastically traditional in its layout and composition, the mathematics class, while the other was quite literally a woodworking shop with all of the dust, noise, and dangerous machinery associated with it.

The program started in September with the MT teaching in the shop so that the students would not have to transition between classes, though that only lasted for the first few weeks. The MT began by explaining that "in an ideal world" they would be in the same room, but it "wasn't conducive . . . for actually instructing math." The main issue was the excessive noise of the heaters, and desk height (desks were more akin to workbenches and had high stools instead of chairs with backs). The MT felt that they "literally just can't teach in this space anymore." Some exceptions were made later on when activities in mathematics section required the construction space: "Now we have brought some of the things up and used them here. And we've gone down a few times to work with the stuff that's down there, but for the most part we've been up here." Thus, collaboration, while present among the teachers during planning phases of the program, was not implemented on a daily basis in front of the students or during actual instruction time—the classes themselves tended to remain isolated, in terms of the teachers presenting the material.

The idea of team teaching or teaching with other teachers in the same class came up during interviews. While it did not happen consistently during the program (it only took place for a few classes at the beginning of the semester), the MT appeared to not be

very comfortable with the idea— “I haven’t done that very much, and to be honest I’m not super comfortable.” This idea of comfort level while teaching in front of your peers is an important consideration whenever implementing collaborative programs like TechnoMath.

The TT expressed feelings of pressure when it came to working out the logistics of larger projects and getting the required materials— “personally I do feel the pressure on some of these larger projects.” Though they were quick to point out how helpful the MT was throughout the process, this did not change the TT’s feelings regarding expectations put on them to execute material-heavy projects. “I mean my partner’s been really good with any logistics we needed to do, [they’re] right on board with it. Umm, but yeah, I had to figure out how to build all that, I had to make sure the material got here.” It is important to note, however, that both teachers went out to pick up the supplies when the time came. Though, this anecdote does remind us that no matter how evenly duties are divided, pressures will always be different due to the different nature of the courses that each teacher taught and the different experience levels present.

The idea of the professional experience differential between the teachers was addressed by the TT during the interviews. It was prompted when I asked them what they learned from their partner:

I think because I’m so new it was good to see someone else and hear [their] thinking and be able to bounce ideas off [them] and just mostly [their] approach to how [they] did what they did. . . . I think that was the most valuable thing that I would take away from it. I guess the thing of it is because I’m so junior and [they’re] more experienced, it’s not like a mentor-mentee sort of thing because we’re supposed to be partners doing this, but that would be, I think, would be what I took from it, is how [they] thought

about these issues or how we should approach planning and what was important to [them] and what wasn't.

The MT's response to the same question centred around the previously mentioned ability to be flexible around the "real world" challenges surrounding teaching in technology as well as the acquisition of some woodworking skills from their partner:

. . . it's the flexibility part. That in the real world, which is what, in my mind, [their] world is, the real world, right? And, so materials don't get delivered when they are supposed to be delivered and . . . yep, it's not happening today, so we're going to do this instead.

Interestingly, their reply also contained an anecdote describing a collaborative effort in solving a challenge for the TT's personal project:

[They—the TT] and I were working one day and [they] wanted to make a shelf, a bookshelf or something for [their] partner and it had to be. Oh, I know, it was a thing...it went on the wall, but it needed to be a hexagon, so [they] and I were figuring out the angles together, and [they] were telling me how to cut these angles, and so it was kind of cool.

This story represented the subject integration and collaboration occurring in TechnoMath on a micro scale—two people from different disciplines relying on each other's unique expertise to complete a common objective. This example highlights the transferable nature of what the teachers had learned and how they carried it from their school environment to a personal one.

4.8 Financial and Planning Challenges

The financial and planning challenges themes centred around codes relating to costs associated with the TechnoMath program and issues with planning that the teachers had. These two themes were paired as financial considerations were heavily interwoven with time and planning issues throughout observations.

The uncertain nature of program funding brought about by recent changes in provincial leadership presented the program with financial challenges. It was clear from the interviews and observations of teacher's affect during some questioning relating to funding that the relatively recent election of the Ontario conservative government did not inspire confidence in potential future funding of the program. The MT felt it odd that a planned provincial TechnoMath training session early on in the summer of 2018 was cancelled with short notice—“[The cancellation] must have cost a fortune in my mind, because they still had to pay for my hotel, because I couldn't cancel it. Right?” They wondered aloud that if the provincial government was already obligated to foot the bill for previously arranged transport and accommodation, “why not do it?” They thought it perhaps served to “make a statement” to educational boards. Initial TechnoMath teacher training was later conducted in the summer weeks before school was scheduled to restart, though, at that time, funding was still uncertain, so the costs were absorbed locally by the board. It was with these kinds of political worries and abrupt distributions that the TechnoMath program began.

Despite these initial worries, there was more of a shortage of time than of money throughout the program. The TT stated that “At times, it was hard to get time—like we have all this money for release time to collaborate—but it's hard.” This is primarily

because it is difficult to find substitute teachers with qualifications to supply teach within the TE context, the MT also did not want to take time away from class to plan as a supply teacher would not be up to speed on what the TechnoMath program was. The TT elaborated on what they thought of their planning time and frequency and the state of their funding more than halfway through the program's duration.

We didn't really have a lot of great time to sit down and say 'OK, this is why we're going to do this, this is how.' We lost our planning time this summer, so we feel like we're playing catch-up, it was a week before school when we met and then the projects were changing, and I still haven't heard that our funding is in.

There were two primary ways money was being spent during this program. The first was in teacher release time so that they can take the school day off to plan and pay the supply teacher to replace them for the day—as mentioned above—the second was for materials, primarily for construction projects. One solution that was considered to supplement material costs was to do community projects for local businesses or charities, much like the ramp project, though this presented its own challenges. The TT felt as though this added extra pressure on them as they were working with “other people's money at that point” and “they're kids,” meaning that a business might not be as forgiving if students make mistakes that cause that business to lose time and money on a project that they fund. This was not an issue in the end, as there was enough of a budget left over to absorb any mistakes made in the ramp production; though the TT had to fix them or make new ramps themselves after the school day in order to adhere to the specifications of the organization contracting out the work: “It was tough, and I'm not done, that's the other thing, too. Now that we've taken all these on, I still have things that I have to produce, so I have to make at least 6 of the 8 ramps, fix them, so I have to order

material to fix them.” The TT also stated that “next year I don’t think there will be a budget” as it would not be replenished, meaning the program essentially ended in the 2018-2019 school year.

The TT described what they think went wrong with planning and how it could have been better:

But I think it could’ve been more cohesive and more integrated in the way we approached it. It’s just that, I think it would take a lot more work, maybe more time than we have, and I don’t know how you get—you have to start sooner. So, we would’ve had to have known in the summer, maybe had some planning before we even left [for the summer] I think that would’ve helped more. I think that’s probably the best answer I’ve got.

The MT agrees with this analysis when they responded to the same line of questioning:

I think it would be nice to have the—and whether this is feasible or not—is to have the projects figured out ahead of time, which was supposed to be part of the summer plan. . . . If we had those organized ahead of time, before September, and then could design around three projects . . . I think, the more we connected with the projects the better.

The main factor in the issues the teachers had around planning seemed to have centred more on requiring more time to build curriculum and lesson plans for the TechnoMath program rather than needing more money.

4.9 Summary of Key Findings

TechnoMath’s main goal was to facilitate students’ connecting of concepts in TE to their underlying mathematical principles. Analysed data yielded seven key themes: (1) Teachers’ readiness; (2) Assessment; (3) Student experience and learning; (4) Subject integration; (5) Curricular content; (6) Collaborative practice: and, (7) Financial and

planning challenges. There were noticeable differences in experience among the two participant teachers in the study, despite this, they had similar opinions on how the TechnoMath program ran and their own preferences for working with peers in integrated programs. Both teachers admitted that they preferred not to teach in front of their peers, citing an affinity for personal and professional space while conducting lessons in the classroom—they did, however, enjoy the collaborative process of building curriculum, problem solving challenges, and learning from each other’s disciplines throughout the program. They also demonstrated collegial attitudes towards each other and their time together during the program. TechnoMath facilitated the teachers’ revealing of the deeper mathematical connections underlying the construction projects to the students —without the teacher collaboration behind TechnoMath, the TT would not have had the time or expertise to effectively teach the mathematics behind the projects as well as do the construction projects themselves.

The TT stated that they felt TechnoMath was “largely the same” as what they were teaching in other classes, though the approach was different; mathematics played a more pivotal role. Participants did agree that assessment was one of the factors that was different when comparing technomath to regular curriculum. Assessment presented its own challenges as teachers were still expected to provide individual grades (per discipline) instead of a unified ‘TechnoMath grade,’ though the sharing of student information amongst participant teachers helped to provide more context in assessment and evaluation of the students. The teachers also reported that student engagement levels were lower than they had expected prior to starting the program.

During teacher training sessions, TechnoMath was explained as a fully integrated program in which the mathematics curriculum worked in synergy with TE—the idea was to blur the lines between these two disciplines and discourage the appearance of “two islands” of subjects. Despite these intentions, the participants identified that the program still felt like two separate classes instead of one unified program and were unsure of how to make it feel more integrated.

Chapter 5

Discussion

5.1 Introduction

This case study's research questions centered around the process of teacher collaboration throughout the TechnoMath program, associated challenges faced by teachers throughout its implementation, and any benefits or weaknesses identified by the participants during their experience. In discussing both subject integration and teacher collaboration examined throughout the case study, it is my intention to arrive at meaningful conclusions relating to the research questions as well as any possible recommendations for future research, and limitations to this study.

The purpose of this case study was to examine how the participant teachers in the TechnoMath program collaboratively applied integrated teaching in their program. This led to the construction of the three research questions that guided the research:

- (1) How do two teachers collaborate to deliver an integrated TE and academic mathematics program?
- (2) What challenges do teachers face during integrated teaching of the TechnoMath program, and how do they navigate these challenges?
- (3) What perceived benefits and weaknesses do teachers identify in the TechnoMath program?

While reviewing the literature for this study, it was evident that research was lacking in the area of interdisciplinary programs involving Technological Education and academic subjects. Moreover, a lens focusing on teacher's collaborative practice while

conducting these programs was equally missing in the reviewed literature. This study seeks to contribute to the filling of these gaps.

While program subject matter was interdisciplinary in nature, projects and lessons integrated both disciplines present in the program, physical space—the classrooms—and assessment strategies were still treated traditionally as they belonged to their respective individual subject areas. At times, this served to break the illusion of integration to a degree, though the program would still fall under the definition of integrated learning according to the literature (Drake, 2012). The individual subjects taught in TechnoMath did not significantly differ in their delivery and design as compared to their non-integrated forms—a backwards design philosophy was used to plan most of it. The differences as compared to a non-integrated program, however, were in the scale of projects teachers were able to assign as students now had two periods instead of one to work on an assignment and two teachers from separate disciplines to help design them.

5.2 Teacher Collaboration and Subject Integration in TechnoMath

The bulk of this chapter is centred around the research questions and the main themes explored in Chapter Four—mainly results centering around Subject Integration, Teacher Collaboration, and how they relate to the research questions and extant literature. These two main areas of focus are what inspired the headings for this section (5.2). It is divided into three sub-sections: Subject Integration—Its Implementation, Challenges, and Benefits; Teacher Collaboration; and, Practical Challenges with TechnoMath. These three sections address the three research questions from multiple perspectives. Each section addresses the three research questions within the context of the section’s topic—for example, the subject integration section focuses on how subject integration took place

within the program, any challenges that teachers experienced with integration, as well as any benefits that they may have identified.

5.2.1 Subject Integration—Its Implementation, Challenges, and Benefits

Subject matter taught in the program “revolve[d] around a common theme” and “skills [were] emphasized across subject areas” (Drake, 2012, p. 18). As per the TT, students were encouraged to take “concrete” concepts and put them “to real use.” This approach was evident during the first project that took place in the program’s delivery during the case study. In it, students designed and built a garden planter for the school. They were required to use lessons learned during the mathematics class component to calculate volume, surface area, conversions from board feet to linear feet, and had to estimate the material cost of the planters they built. The TT described this kind of subject integration as “the most complete project” done in the year and the opposite of “doing something and then ... tack[ing] the math on in some creative way.” The TT’s description of the activity and manner in which material was delivered to students during these successful projects where the students “bought in a little more” (e.g. the garden planter project) was reminiscent of Hogaboam-Gray and Ross’ (1998) description of subject integration—subjects are not separated into discreet streams. The results of that study do not necessarily mirror those of the TechnoMath case study where the participants actually reported lower student engagement with the content.

Hogaboam-Gray and Ross (1998) observed that in the integrated environment, students experienced higher levels of motivation and engagement. In the case of TechnoMath, both participants, expecting the same as the previously mentioned study, expressed surprise when they revealed that student engagement during the program was

actually lower. One of their justifications for this lack of engagement was attributed to a specific group of students in the class, as well as their age range (Grade 10) —a range which the MT described as “the most tumultuous” of all the grades in high school. Another reason for this lack of engagement given by the participants had to do with administrative decisions, as identified in the financial and planning challenges theme in the analysis. Since this was the only grade 10 mathematics class offered in the semester, students enrolled in it were automatically added to the accompanying construction class that comprised the TechnoMath program—leading us to conclude that not all students chose to be there. While these justifications may indeed be factors, and credible ones from seasoned professionals, they are nevertheless only one perspective. During observations, there were innovative uses of technology in the mathematics class, though at times, however seldom, certain content was delivered in a teacher-centered way and the students’ engagement suffered as a result. This engagement behaviour did not appear to be as much of an issue during the construction class portion of TechnoMath as students were mostly physically engaged in woodworking. However, as evidenced by in-class observations, when a teacher-centered approach was taken, or when students were required to do written work at their desks instead of using machinery and hands-on activities, student engagement also suffered. For example, in an observed instance, students working at their desks on a design worksheet required before starting woodworking quickly went off-task.

A major challenge faced by teachers during the implementation of the TechnoMath program were the distinct differences between the mathematics and construction classroom environments. These differences in environment served as an

additional means of separating the subjects, thus hindering integration and highlighting the different milieus in which each subject's learning took place. The initial intent at the beginning of the program in September was to avoid this and have both classes taught in one space. Instruction in the same space for both classes occurred for the first few weeks in the woodworking classroom space but ended up being temporary as the space being used was not conducive to delivering mathematics lessons. As per the MT, the space was too noisy when the heaters or ventilation would turn on and they "literally just [couldn't] teach in this space anymore" as a result. This separation in subjects was also felt by the teachers at times. The TT stated that they think that they are both "operating separately" in the sense that "there is a math class and there is a tech class." Drake (2012) would classify this type of subject integration, where there is a unifying theme that ties individual class together as Multidisciplinary or Parallel Curriculum. This classification goes against the initial intent of TechnoMath being an Interdisciplinary program—it was stressed during orientation that TechnoMath was not to be "two islands," and that it was to stay integrated throughout its implementation.

The TT described their processes in class as "largely the same as what we're doing in my other classes, the difference I guess, is what we're focusing on, and how we're approaching it ... because we really want to be able to use math, because that's kind of the whole focus." Without intensive planning time, something which was observed to be lacking throughout the program, teachers had a tendency to default to mathematics-centric lesson plans in which mathematics was "tacked" on, as stated by the TT. This is echoed in teacher descriptions of what drove planning criteria: the TT finds a project and the MT works out which part of the mathematics curriculum applied—or as

they (MT) put it: “I have to hunt and peck and see which parts, which expectations can be met with this project.” What made the garden planter activity so successful? I believe the answer to this lies in the dedicated time— “a week before school started,” according to the TT—the teachers had right before the start of the semester to plan it. Though it was not as much time as they had originally planned on, the TT mentioned during interviews that they had lost planning time allotted in the summer, it was the only period during the program where they were not “playing catch-up” with more lesson planning, assessment strategies, and their other obligations to the two other courses they were teaching that academic year (three classes per semester is considered a full work load for high school teachers in Ontario). The TT described the schedule as “tougher to control” as the year went on; this was also noted in observations showing that activity scheduling became more and more complicated as the semester progressed. The idea of “playing catch-up” and losing control of the schedule as the year progressed confirmed Hogaboam-Gray and Ross’ (1998) findings that, while integrated curriculum can greatly benefit learners’ engagement and performance, it can also be difficult to execute as the year progresses due to its increased complexity.

5.2.2 TechnoMath’s Strong Start

Upon observing the variety of TechnoMath lessons and the teacher feedback provided throughout the program, one concludes that the garden planter lesson—the first lesson—was the most successful example of subject integration and, as a result, was the truest to the TechnoMath ethos. That is, the idea that the program did not turn into two distinct classes of mathematics and construction, but rather, one TechnoMath program. Feedback from the TT during interviews surrounding the planter activity revealed that

“nothing was as good as that afterwards because it was really integrated.” The lack of student engagement in class that followed this activity throughout the rest of the term could be associated with the identified decline in levels of integration that took place in the lessons and projects that followed. The experience of subject integration by the teachers in this case reflects Hogaboam-Gray and Ross’ (1998) understanding of subject integration with their caution that, when executing subject-integrated programs, the increase in organizational complexity as the program progresses can lead to teachers losing track of the “structure of the disciplines” along with more difficulty in students’ abilities to make “vertical connections” between previously learned subject matter (p. 1121). This loss of ability to make connections in the subject matter can be one of the reasons for students’ waning in engagement throughout the program as the increased interconnectedness of the program led to overcomplexity in learning.

Observed successes in the delivery of integrated curricula in Hogaboam-Gray and Ross’ (1998) study were predicated on the fact that teachers involved had had four years to develop the program—gradually increasing the number of integrated projects and teachers involved as they refined curriculum delivery in an integrated setting. Hogaboam-Gray and Ross finished their paper with a warning: “Teachers who leap into ambitious integration programmes developed by others without first engaging in the lengthy professional learning process that the Bayview teachers went through are unlikely to get the same results” (p. 1133). Research suggests that high levels of professional development are necessary for proper implementation of programs and curricula involving subject integration. In the case of TechnoMath and the results that were both

observed in the classroom and recorded in interviews, Hogaboam-Gray and Ross' recommendations were confirmed.

5.2.3 The Need for Administrative and Ministerial Support

Conroy and Walker (2000) also point to the necessity of having administrative support for the teachers in order to properly deploy professional development and properly structured student timetables conducive to integrated programs. When these support structures were not in place, according to Conroy and Walker's research, "teachers were only as successful as their individual efforts and those of others involved, often at their own expense" (p. 60). Conroy and Walker's research echoes themes found in this study centering on planning challenges—particularly those centered on time constraints surrounding planning—experienced by teachers throughout the TechnoMath program.

Fundamentally, planning challenges in the TechnoMath program largely occurred because teachers were given the responsibility of curricular mapping as well as lesson planning and design. In the future, further ministerial and administrative support given in these areas in order to offload some of the work from the teachers would provide them with the much needed time and mental space to focus on lesson planning and student assessment.

5.2.4 Teacher Collaboration—How Teachers in TechnoMath Worked Together

While student motivation and engagement were not as high as the participant teachers had expected, a positive outcome of TechnoMath included an observed increase in teacher collaboration, inter-departmental teacher relationships, and conversations

resulting from the required co-operation needed to implement the program. This increase in collaboration was reflected in participant observations during planning time where they worked together to solve issues present in lesson plans—figuring out complex documentation regarding ramp construction issued by a local non-profit for an activity, and navigating materials logistics required for projects come to mind as exemplars of this behaviour.

Participant teachers used collaboration to face challenges. Throughout the observed TechnoMath program, it was clear that teacher collaboration was taking place—not only in order to help deliver an interdisciplinary model of subject integration, but also to help overcome challenges that arose during the semester. Collaborative practice (frequency = 39) as a code was second only to planning issues (frequency = 56) in its occurrence in the data. In fact, a key finding was the presence of positive collaborative and collegial habits among the two participants despite challenges in sharing workspaces, issues surrounding a lack of planning time, and a difference in the participating teachers' experience and familiarity with each other's subject areas. Observations conducted during teacher planning sessions were demonstrative of this behaviour. This collegial collaboration resulted in the successful implementation of lessons during the program.

Collegiality is defined in the literature as the “quality of the relationships among staff members,” and was found to be associated with sympathy and solidarity regarding work; while collaboration is seen as a collective interaction “in all activities that are needed to perform a shared task” (Vangrieken et al., 2015, p. 23). Both of these qualities are critically important for the proper functioning of a subject integrated program (Vangrieken et al., 2015). The degree to which teacher collaboration occurs is also

important to note. Vangrieken et al. (2015) cite five levels of collaboration: “storytelling and scanning for ideas, aid and assistance, sharing, joint work, and teamwork” (p. 26). The teamwork level implies strong levels of co-dependence throughout their practice.

5.2.5 Pooling Skills to Excel as a Team

A prime example of teamwork in this program was the teachers’ collaborative delivery of material during the ramp making activity. The students were required to use trigonometry in order to successfully build the ramps in the construction class. The MT had the knowledge required to effectively and efficiently deliver trigonometry lessons to the class; the TT admitted that they would not have been able to do the same themselves in the construction class as it would have been “too complicated” to achieve in a timely manner. During interviews, the TT stated that the construction program was essentially “applied science and math” at its core. The inclusion of a trained and experienced mathematics teacher in the dissemination of a construction curriculum is a logical choice if one were to want to improve student learning. The MT also identified benefits from this relationship—they took lessons used during the TechnoMath program that were more construction based (the catapult lesson, for example) and planned to use them in their own practice in future mathematics classes. These examples are demonstrative of Venville et al.’s (2000) study that found that subject knowledge proved to be less of a barrier in integrated subject programs because teachers “pooled their skills” when working collaboratively (p. 35), as well as the idea that teachers who collaborate were shown to be more effective at their work than those who do not (Spillane et al., 2018). Johnson’s (2003) findings that teachers collaborating with each other more frequently engaged in professional development opportunities and the breakdown of “traditional

subject barriers which previously inhibited learning and sharing expertise across subjects” were also confirmed (p. 344). Without the teacher collaboration involved in structuring this lesson and synchronizing its delivery, it would not have been successful.

It was evident through observation that teachers displayed positive collaborative behaviour throughout the program. The participant teachers worked productively during planning and preparation phases of the program. This collaboration included meeting on the weekend to pick up lumber supplies for projects, meeting before school or during prep periods to plan lessons, and sharing the classroom space at the beginning of the term. The TT described the MT as their partner and being “right on board with it” when referring to working together in TechnoMath. This co-operative behaviour extended outside of TechnoMath planning and into helping each other with personal projects like figuring out the appropriate angles for a shelf the TT was making for their partner. This extension of a collaborative spirit into non-professional work is indicative of a relationship with strong ties and indeed a positive result of the TechnoMath program.

5.2.6 Professional Workspace and Assessment in the Context of Collaboration:

Together but still Separate

Observed teacher collaboration mostly took place during planning phases as both teachers indicated that they were less open to teaching in front of other teachers and sharing classroom space on a long term basis. Expressed feelings in this area included the MT stating that they would rather be “in [their] own room with the door shut” and not being “super comfortable” with the idea of teaching with a peer simultaneously. Teachers in this study showed a high level of possessiveness of their own professional space—their classrooms. Phrases used by the teachers to show this characteristic for private class

space included: “it’s nice to have your own room that you don’t share with anybody else, that you can set up the way you want” as stated by the MT; and, “you want it to be your space that you take care of because once you teach, no matter what you teach, it’s nice to have your own room that you don’t share with anybody else, that you can set up the way you want, and teachers really like that” from the TT. This phenomenon was not found in the literature during the research phases of this case study. While the subject matter was integrated in TechnoMath, there were still clear separations taking place. Workspace presented itself as one of these divisions, assessment was the other.

A large part of the collaborative work that took place during the program related to assessment. Both teachers expressed difficulty in assessing students on individual disciplines (mathematics and TE) while engaging with them in an integrated program. The TT expressed that they were “trying to figure out my way through it,” indicating that assessment strategies were not solidified from the beginning of the program. This uncertainty regarding assessment strategies is not that surprising when one considers this was the first time that either of the teachers was engaged in TechnoMath. Giving the students a combined grade was entertained, but impossible since it would require one teacher to teach both subjects in the program.

An upside to assessment in this context, however, was the fact that the teachers were able to share student data with each other. While sharing of data could not count towards formal assessment, it did give each teacher a more “complete picture”, and a sense of greater validity in their assessment of student achievement and behaviour, something that could help inform assessment strategies and even help teachers modify or accommodate curriculum for their students to learn more effectively. There was a

noticeable gap in the literature regarding teacher assessment strategies and challenges in interdisciplinary models of education, suggesting that this would be an area where future research is necessary.

5.3 Practical Challenges with TechnoMath

5.3.1 Logistical Challenges

Given the nature of the TechnoMath program and its heavy reliance on physical construction materials for its proper execution, logistical issues contributed to the challenges faced by teachers during the program's implementation. These challenges included delays in deliveries of project materials (lumber, fasteners, etc.) to the school which then required an unplanned weekend trip by the teachers to the lumber yard to pick them up. "Materials don't get delivered when they are supposed to" was an observation the MT made that reflected how things went wrong at times. Logistical challenges such as these further add to the organizational complexity surrounding integrated programs—the fact that one of the courses being taught in TechnoMath was in the TE stream adds additional difficulties as it is often a materials-dependent class to teach. This further reinforces Hogaboam-Gray and Ross' (1998) finding that an integrated curriculum's organizational complexity increases throughout its implementation, as well as Zhou et al.'s (2011) findings that collaborative programs are more time consuming as a result of the added planning involved in its implementation. In negotiating these hurdles, teachers exhibited flexibility in their curricular choices and fortified their collaborative relationship with each other. To handle these unforeseen challenges, they were required to co-ordinate changes necessary to student learning until said materials became available or were delivered. As was demonstrated earlier in chapter four, flexibility—referenced

nine times during coding—on the teachers’ part was a necessary quality to deal with these challenges. Sometimes this meant that the TT would make “place-holder” activities like building shelves, and the MT would teach a concept that was difficult to link to construction. These non-integrated activities not only interrupted the flow of learning and reinforced a separation of disciplines in an environment that was encouraging the exact opposite, but would also “squeeze” into the time of other projects essential to the program, as was the case with the previously mentioned shelf example. The hardest part of all of this, according to the MT, was to “make the timing mesh,” further highlighting the complexity involved in integrated programs as reviewed in the literature (Hogaboam-Gray & Ross, 1998). Though these challenges—especially ones pertaining to timing—certainly presented the teachers with difficult situations, their collaborative strength helped them to overcome the majority of the obstacles they faced. One of the lasting effects of these “place-holder” activities, however, could have been the contribution to a further breaking of subject integration leading to further student disengagement.

5.3.2 The Added “Burden” of Collaborative Planning and Associated Temporal Constraints

Further drawing from the literature on challenges surrounding time in teacher collaboration, in their scoping review on collaborative inquiry, DeLuca et al. (2015) found that temporal constraints were a common issue experienced by teachers. These findings were reinforced by observations conducted during the implementation of TechnoMath as a large portion of codes linked with challenges generated during analysis were associated with timing issues—26 instances. The experiences revolving around time constraints in teacher collaboration by participants in this case were also reflected by

Johnson's (2003) study examining collaboration and its implications. He found that teacher collaboration placed "an added work burden on teachers," resulting in less time over all for teachers to effectively do their jobs (Johnson, 2003, p. 346). Along with planning their original subjects, teachers in the TechnoMath program also had to factor in subject integration, logistical concerns, and curricular mapping, adding to their workload. Teachers were also lacking support in the form of not having trained supply teachers that would be able to continue the TechnoMath program in the MT and TT's absence—thus, not allowing them to take advantage of funded release time to plan curriculum during the semester.

Overall, the main practical challenges experienced and identified during this case study were associated with time and logistics. Through strong collaboration, however, TechnoMath teachers worked well to overcome these challenges, though the impact of delayed projects due to these obstacles was lasting throughout the semester and teachers felt a domino effect in their schedules as a result.

5.4 Contribution

This case study contributes to the literature on teacher collaboration within a program integrating technological and academic curricula. Specifically, evidence from the case suggests that : a) Teachers in this study enjoy collaborating on lesson planning and curriculum design, though prefer not to teach in front of peers or share the same teaching space for prolonged periods of time; b) Despite using similar curriculum to non-integrated programs, TechnoMath allowed teachers to deliver larger-scale projects to students as they had more collective class time to work on them (as compared to a single-period class structure); c) TechnoMath assessment presented unique challenges as student

projects took place over both classes, and teachers could often only take the perspective from their own class due to class timetables, meaning that teachers chose not to see the other half of the student assessment picture first-hand. Teachers did talk to each other about student behaviours and Learning Skills issues, however; d) Student engagement was not as high as the teachers expected; e) Teachers' expectations were that they were teaching transferable skills to their students, who would in turn demonstrate those skills in class projects; f) Subject integration in TechnoMath offered the opportunity for students to see and use examples of real-world application of abstract mathematical concepts; g) Planning time and logistics surrounding gathering project materials were two of the most significant challenges faced by teachers. Much of the teachers' time was taken up by logistical issues surrounding building supplies and materials, and curricular mapping and lesson planning.

While previous literature has identified the necessity for and benefits of effective forms of teacher collaboration (Vangrieken et al., 2015; Spillane et al., 2018; DeLuca et al., 2015; Zhou et al., 2011; Johnson, 2003), few studies (Hogaboam-Gray & Ross, 1998) have framed it within the context of subject integrated programs such as TechnoMath. My research noted some of the challenges and benefits teachers experienced while teaching a curriculum integrating both applied and TE subject streams.

5.5 Limitations

While findings from this study help in advancing our understandings and practical strategies for integrated teaching and learning, they should be considered within the scope and scale of the study, and in relation to the study's limitations. The scope of data in this case was limited to observations conducted during planning sessions and active

teaching time in the classroom throughout the first semester of the 2018-2019 academic year during the implementation of the TechnoMath program—a total of five visits were made to the school for observation along with the observation of the school board’s orientation session prior to the 2018 start of the school year. Conducting observations of both students and teachers before and after the program would have provided further insight into the impact of the program in relation to the learners’ academic achievement levels and any long-term pedagogical influences on teachers. Though this program stopped running after my observations—due to enrollment and funding issues—had it gone on, it would have been fruitful to continue observations in a setting where the teachers had previous experience in delivering integrated curriculum. An examination of the student perspective (e.g., via interviews, focus groups, or survey) and their academic performance (e.g., via collection of assessment data and classroom artifacts) would have also allowed for a more holistic picture of the benefits or drawbacks of such a program

This work was not conducted by someone who is completely removed from the field of TE. As a practicing teacher in this area myself, I have a strong interest in interdisciplinary education and see its value in this context. Future research from different positionalities is warranted and will add to more diverse perspectives on the topics covered in this research.

5.6 Recommendations for Future Research

Based on this study’s findings, the following are suggested as targeted areas for future research: a) Teachers’ perspectives on personal and professional space in a collaborative environment and how they affect the delivery of integrated subject models; b) Assessment strategies in the context of integrated programs; c) Interdisciplinary

programs that integrate technological and academic curricula and how teachers and students are able to differentiate (or not) between the two subject streams within the context of the program; and d) Student engagement and motivation in the context of integrated programs.

Future research in the area of teachers' perspectives on their workspace within the context of an integrated program and teacher collaboration were inspired by findings obtained through observational data as well as interviews that suggested teachers can be possessive of their own teaching space—participants had shown an affinity towards keeping their classrooms as their own since so much work had gone into organizing them how they preferred. During the TechnoMath program, the initial intention was to have all learning occur in one space, this was found to be difficult as mathematics and construction classes each demand different kinds of classroom layouts. Research into the types of learning environments conducive to integrated programs like TechnoMath and how teachers collaborate and share within that space would not only be fruitful towards furthering the efficacy of such programs, but also tell us if these types of integrative programs have any chance of success when they do not have access to these types of agreeable spaces.

To ensure future successes of integrated programs like TechnoMath, research suggests that a possible future step for programs like TechnoMath is to increase professional development opportunities for participating teachers, to consider multi-year teacher participation in the program, as well as implementing peer-to-peer training in which senior TechnoMath teachers mentor other teachers new to the program (Conroy & Walker, 2000).

Assessment within the context of integrated programs merits future research, as well. Findings in this paper suggest that assessment during TechnoMath was an area that teachers struggled with throughout the semester. Assessing student work in a context that is supposed to be unified under one program yet divided into two physically different classes or spaces proved to be a challenge for teachers to navigate. Further research into this area would help inform future training and assessment design for subject integrated programs like TechnoMath.

During the literature review phase of this study, the relative lack of recent research done in the field of integrated curriculum programs involving academic and TE disciplines suggest that this area of work is unresearched and that, in my opinion, it should be examined more deeply. Future research could prove invaluable to educators seeking to design and implement interdisciplinary programs like TechnoMath—programs that, if implemented effectively, can deliver curriculum to students in ways that illuminate concepts that they may not have otherwise seen in practical applications. If these program designers have access to current and meaningful research in this area, they are likely to avoid issues encountered in the first year of such a program's implementation. Future research in the field could also more substantively explore the role and supports needed for the effective implementation of curriculum in integrated teaching and learning within the context of TE and academic subjects.

Throughout observations conducted during TechnoMath, it was clear that student engagement and motivation were not as high as the teachers had expected; these results also appeared to contradict existing literature. These contradictory findings merit further investigation as they could highlight shortcomings relating to integrated programs within

the context of student engagement and aid in designing future programs that are more engaging to their participants.

Finally, a longitudinal version of this case study would improve the rigour of the work being reported due to increased time in the field. Though for such a study to be conducted, there would have to be stability in the program's funding and implementation at board and ministerial levels. Despite the lack of longitudinal observations in place, this research did observe board training, teacher planning sessions, and actual TechnoMath class time, thus providing as complete an overview of the program as was possible given its running time of one semester.

5.7 Conclusion

There is great potential in the TechnoMath program, but more structural support is required for it to reach higher expectations. Planning time, a classroom layout that could better accommodate both TE and academic styles of delivery, support from administration vis-à-vis student enrollment, and more concrete assessment strategies going into the program would all contribute to greater success in the future. Teacher collaboration in the delivery of integrated curriculum led to more in-depth exploration of concepts in both disciplines included during the program and students stood to benefit as a result. Teamwork did indeed make the dream work, to an extent, but the dream needs to be bigger and better supported if we are to take advantage of the potential benefits of integrating TE and academic disciplines.

Questions of classroom space and assessment brought about significant challenges to the program's execution. Teachers were unsure of assessment strategies and had to modify their approach during the program's enactment. Initial intentions to

conduct the program in the TE space for both classes were quickly changed as the space was not suitable for mathematics instruction due mainly to noise considerations of the class' heating and air filtration system. This study helped to highlight these issues of teachers' space within a collaborative context and offer a contribution to the literature in that field, though further research would also prove beneficial to better understanding the dynamic that teachers' workspace plays in programs like TechnoMath.

This research found that logistics and planning time were the most significant barriers to proper execution of the program throughout the semester. Teachers became overwhelmed by the program due to lack of planning time throughout the semester. There was little flexibility in the teaching schedule, any unforeseen material supply issues quickly destabilized essential project timelines and forced teachers to play "catch-up" with their original plans. Collaborative efforts, however, were able to mitigate some of these problems. The participants supported each other by meeting to pick up supplies on the weekend if company deliveries were not able to make it on time. They worked collaboratively to deliver both the mathematics and technological design-construction curricula to their students over the course of the semester. The nature of teacher collaboration observed during this program was strong but only centered around planning efforts, most of the instructional time was done individually in each class, though the collaboration that did take place was collegial and at the level of teamwork (Vangrieken et al., 2015). Collaborative efforts also led to problem solving during lesson planning and even for teachers' personal projects at times. Both teachers expressed satisfaction with working with each other and expressed professional growth from the experience. DeLuca et al. (2015) and Zhou et al. (2011) both confirm findings relating to teachers'

relationships with each other and their significance to effective collaboration as they mention the importance of teachers' familiarity as linked to their chances for success in a collaborative setting.

The TechnoMath program implemented interdisciplinary subject design principles. Venville et al. (2000) identified a gap in the literature regarding how students learned mathematics and science in an integrated setting—this study, while not focusing on the learners themselves, contributes to the field by identifying benefits and challenges associated with teaching in an integrated setting revolving around a mathematics curriculum.

This TechnoMath case study serves to further the literature in the domain of integrated programs involving academic and TE courses within the context of secondary school learning. This study illustrates the numerous challenges in executing an integrated program in which teachers work collaboratively to deliver curriculum, but it also shows how educators can come together—no matter how different their disciplines and how adverse the conditions—to create imaginative curriculum that unites two otherwise separate subject streams. In the case of TechnoMath, two heads were indeed better than one.

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Appendix A

Sensitizing Concepts

Sensitizing concepts to be used during field observations:

- Teachers' navigation of integrative and collaborative practices.
- Student reception to presented interdisciplinary concepts.
- Teacher's negotiation of concepts presented that do not lie in their original curricular expertise.
- Spontaneous moments of subject connection by students (Eureka moments).
- Student engagement with subject matter.

Appendix B Interview Questions

Individual Interview Questions

- 1) How long have you been teaching in your subject area? And before that, what did you do?
- 2) How would you define the kind of teaching you've been doing in TechnoMath?
- 3) What has your experience been with interdisciplinary teaching in the past? Did you like it?
- 4) Have you taught in your partner teacher's space during this program? For how long? How did you feel about being in that space?
- 5) Have you received support from Administration (School/Board/Ministry) for TechnoMath? What kind?
- 6) Has TechnoMath changed the way you teach/will teach? How/Why?
- 7) What difficulties have you encountered during your implementation of TechnoMath? How did you navigate them?
- 8) How does TechnoMath differ from past classes you've taught in the same subject area?
- 9) Have you noticed a difference in student engagement and learning during TechnoMath (as compared to previous, non-TechnoMath classes)?
- 10) How would you define your relationship with your partner teacher now as compared to last year? What about with teachers from other departments (not your own)?
- 11) What would you do differently if you were to teach this program again?

12) What lesson would you say you've learned from your partner teacher, if you could identify one?

13) Would you participate in TechnoMath again? Why?

Group Interview Questions

- 1) Picture yourselves in August of 2018, could you tell me what your expectations were of the program, collaborating with another teacher from a different department, and how you think the students would engage with it (TechnoMath)?
- 2) Now given your experience with the program, were those expectations met?
- 3) What did you like about working with each other/ another teacher? And what would you change?

Appendix C

Queen's University Ethics Clearance



September 28, 2018

Mr. Luis Santos
Master's Student
Faculty of Education
Queen's University
Duncan McArthur Hall
511 Union Street West
Kingston, ON, K7M 5R7

GREB Ref #: GEDUC-925-18; TRAQ # 6024706

Title: "GEDUC-925-18 Team-work makes the dream work: Teacher experiences with interdisciplinary integration in technological education"

Dear Mr. Santos:

The General Research Ethics Board (GREB), by means of a delegated board review, has cleared your proposal entitled "GEDUC-925-18 Team-work makes the dream work: Teacher experiences with interdisciplinary integration in technological education" for ethical compliance with the Tri-Council Guidelines (TCPS 2 (2014)) and Queen's ethics policies. In accordance with the Tri-Council Guidelines (Article 6.14) and Standard Operating Procedures (405.001), your project has been cleared for one year. You are reminded of your obligation to submit an annual renewal form prior to the annual renewal due date (access this form at <http://www.quccnsu.ca/traq/signon.htm>) click on "Events;" under "Create New Event" click on "General Research Ethics Board Annual Renewal/Closure Form for Cleared Studies"). Please note that when your research project is completed, you need to submit an Annual Renewal/Closure Form in Romeo/traq indicating that the project is 'completed' so that the file can be closed. This should be submitted at the time of completion; there is no need to wait until the annual renewal due date.

You are reminded of your obligation to advise the GREB of any adverse event(s) that occur during this one-year period (access this form at <http://www.quccnsu.ca/traq/signon.htm>) click on "Events;" under "Create New Event" click on "General Research Ethics Board Adverse Event Form"). An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example, you must report changes to the level of risk, applicant characteristics, and implementation of new procedures. To submit an amendment form, access the application by at <http://www.quccnsu.ca/traq/signon.htm> click on "Events;" under "Create New Event" click on "General Research Ethics Board Request for the Amendment of Approved Studies." Once submitted, these changes will automatically be sent to the Ethics Coordinator, Ms. Gail Irving, at University Research Services for further review and clearance by the GREB or Chair, GREB.

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Sincerely,

A handwritten signature in blue ink, appearing to read "Dean Tripp".

Dean Tripp, Ph.D.
Chair
General Research Ethics Board

c: Dr. Ann Marie Hill, Supervisor
Dr. Benjamin Bolden, Chair, Unit REB
Mrs. Erin Rennie, Dept. Admin.

Appendix D

Letters of Information and Consent Forms



Study Title: Team-work makes the dream work: Teacher experiences with interdisciplinary integration in technological education

Name of Student Researcher: Luis Santos, Faculty of Education, Queen's University

Name of Supervisor: Dr. Ann Marie Hill, Faculty of Education, Queen's University

Hello,

My name is Luis Santos, a master's student in the Faculty of Education at Queen's University, working under the supervision of Dr. Ann Marie Hill. I am inviting teachers that are participating in the TechnoMath program to take part in a research study exploring how teachers collaboratively plan and apply interdisciplinary teaching in their practice and how they navigate challenges in the implementation of the program. In this research study, I plan to observe the classes of both teachers involved in the TechnoMath program offered in your Board in Fall 2018. These observations will occur once a week for the entire fall term and will take place in both the math and technological education classes. I will also interview each teacher participating in the study—both individually and as a team—three times over the course of the semester for one hour (each interview) at a location of your choosing. Total interview time per participant will be approximately six hours (3 hours total for individual interviews, 3 hours total for team interviews). The interviews will be audio-recorded and later transcribed. I will also ask participating teachers for Board and teacher documents related to the development and teaching of the TechnoMath program. There are no known risks for taking part in this study. Your participation in the study will help inform how subject integration and teacher collaboration develop an interdisciplinary teaching program. This could help you reflect on your practice and help others understand how a TechnoMath program is planned and taught. The students are not direct participants in the study—no student data will be collected—though I will be observing the classes in their entirety in order to support my investigation that is focused on teachers. The primary focus of data collection will be on teachers' collaborative and pedagogical practices and experiences within the TechnoMath program in order to better understand programs involving interdisciplinary integration with technological education and academic subjects.

There is no obligation for you to say yes to take part in this study. You don't have to answer any questions you don't want to. You can stop participating at any time without penalty. You may withdraw from the study up until November 1, 2018 by contacting me at santos.luis@queensu.ca.

I will keep your data securely for at least five years. Your confidentiality will be protected to the extent possible by replacing your name with a pseudonym for all data and in all publications.

Due to the relatively small nature of this program, there is a chance that participants will be identifiable even though pseudonyms will be used. The code list linking real names with pseudonyms will be stored separately and securely from the data on an encrypted device. No one other than my supervisor or I will have access to any of the data.

I hope to publish the results of this study in my master's thesis and academic journals and present them at conferences. I will include quotes from some of the interviews when presenting my findings. However, I will never include any real names with quotes, and I will do my best to make sure quotes do not include information that could indirectly identify participants. During the interview, please let me know if you say anything you do not want me to quote.

There will be no compensation offered for taking part in this research.

If you have any ethics concerns please contact the General Research Ethics Board (GREB) at 1-844-535-2988 (Toll free in North America) or chair.GREB@queensu.ca. Call 1-613-533-2988 if outside North America.

If you have any questions about the research, please contact me, Luis Santos, at santos.luis@queensu.ca or my supervisor, Dr. Ann Marie Hill, at annmarie.hill@queensu.ca or 613-533-6000 ext. 77432.

This Letter of Information provides you with the details to help you make an informed choice. All your questions should be answered to your satisfaction before you decide whether or not to participate in this research study.

Keep one copy of the Letter of Information for your records and return one copy to the researcher, Luis Santos.

By signing below, I am verifying that: I have read the Letter of Information and all of my questions have been answered.

Name of Participant: _____

Signature: _____

Date: _____



Study Title: Team-work makes the dream work: Teacher experiences with interdisciplinary integration in technological education

Name of Student Researcher: Luis Santos, Faculty of Education, Queen's University

Name of Supervisor: Dr. Ann Marie Hill, Faculty of Education, Queen's University

Dear guardians and students in the TechnoMath program, fall 2018,

My name is Luis Santos, a master's student in the Faculty of Education at Queen's University, working under the supervision of Dr. Ann Marie Hill. I am writing to inform you that I will be observing the teachers taking part in the TechnoMath program at your school. I will be conducting a research study exploring how teachers collaboratively apply interdisciplinary teaching in their practice and how they navigate challenges in the implementation of the program. In this research study, I plan to observe the classes in which TechnoMath is taking place. These observations will occur once a week and will take place in both the math and technological education classes. I will also interview each teacher—both individually and as a team—participating in the study three times over the course of the semester. The study results will help inform how subject integration and teacher collaboration develop over the course of an interdisciplinary teaching program. The students are not direct participants in the study—no student data will be collected—though I will be observing the classes in their entirety in order to support my investigation that is focused on teachers. This letter of information is to inform you that I will be in their TechnoMath course to collect data on teachers' collaborative and pedagogical practices and experiences within the TechnoMath program in order to better understand programs involving interdisciplinary integration with technological education.

If you have any ethics concerns please contact the General Research Ethics Board (GREB) at 1-844-535-2988 (Toll free in North America) or chair.GREB@queensu.ca. Call 1-613-533-2988 if outside North America.

If you have any questions about the research, please contact me, Luis Santos, at santos.luis@queensu.ca or my supervisor, Dr. Ann Marie Hill, at annmarie.hill@queensu.ca or 613-533-6000 ext. 77432.

Sincerely,
Luis Santos