TITLE: STEM Teaching and Learning in the Toronto District School Board: Towards a Strong Theoretical Foundation and Scaling Up from Initial Implementation of the K-12 STEM Strategy. Research Series I

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We have a once-in-a-generation opportunity to create an education system that will develop the innovators, entrepreneurs, and leaders our nation needs to thrive in a global community. (Hanover Research, 2011, p. 10)
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**EXECUTIVE SUMMARY**

The goal of the Toronto District School Board’s (TDSB) Science, Technology, Engineering and Mathematics (STEM) Strategy is to provide professional learning (PL)\(^1\) opportunities and build capacity among TDSB Kindergarten to Grade 12 (K-12) teachers to enhance their STEM pedagogical knowledge, self-efficacy to teach STEM, and promote STEM implementation in classrooms. At the end of the first year of implementation of the TDSB STEM professional learning initiative, our research revealed important findings about administrator, teacher, coach, and student attitudes towards STEM education, STEM teaching and learning practices, and STEM professional learning practices. In particular, the findings provided insights into administrator and teacher perceptions of the value of STEM education; teacher knowledge of STEM pedagogy, resources, STEM careers, and collaboration in Professional Learning Communities (PLCs); teacher confidence and self-efficacy in STEM teaching; the frequency of use of STEM teaching practices to develop STEM competencies in students; student perceptions of teacher practices promoting STEM competencies; and teacher, administrator, and coach perceptions of the professional learning support provided.

Overall, at the end of Year One of the TDSB’s implementation of STEM, the main findings that emerged were as follows:

**Teacher and Administrator Attitudes and Perceptions of STEM**
- Teachers and administrators (over 90%) strongly believed in the value of STEM education for improving student learning.
- The majority of teachers (87%) believed that STEM education would improve their teaching practice.
- Some teachers (19%) and some administrators (26%) felt that a STEM transdisciplinary approach could diminish the importance of individual content areas.
- Teachers (82%) and administrators (98%) would like to see the TDSB STEM strategy continued in schools.

**Teacher and Administrator Perceptions of STEM Competencies**
- Over 90% of teachers felt that they had an understanding of inquiry-based and problem-based learning and understood the importance of integrating content from different subject areas and disciplines when teaching.

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\(^1\) In this report the terms Professional Learning (PL) and Professional Development (PD) are used interchangeably.
• Slightly more than a quarter of teachers (27%) did not have a good understanding of the engineering design process and how to implement it.
• More than half of the teachers (58%) indicated that they had not used the STEM education resources on the TDSB STEM K-12 Academic Workspace (AW) website.
• About one third of teachers (32%) did not know where to find STEM career resources and 23% felt that they did not have a strong knowledge of current STEM careers.
• The majority of teachers collaborated with colleagues (81%) and co-planned with coworkers around STEM (81%).

Teacher Perceptions of their Teaching Practice
• The majority of teachers (84%) reported that they were confident in their ability to teach STEM effectively but 40% wondered, to some degree, whether they had the necessary skills to teach STEM.
• Over 75% of teachers used a variety of STEM teaching practices to develop STEM competencies such as creativity and innovation skills, self-direction, critical thinking, and collaboration skills.
• Only 61% of teachers had students analyze competing arguments, perspectives, or solutions to a problem to develop critical thinking skills.
• Thirty-one percent (31%) of teachers never or rarely discussed issues related to global interdependency and 14% of teachers never or rarely had students reflect on how their experiences and local issues connected to global issues.
• Teachers implemented some STEM-related activities and projects more than others. The most popular activities were: hands-on activities (90% of teachers), experiments (67% of teachers), and using computer technology for data collection, analysis, and presentation (64% of teachers).
• The least used STEM-related activities were: co-op opportunities with business and community partners (3% of teachers), site visits (14% of teachers), and robotics (23% of teachers).

Professional Learning and Organizational Support
• The professional learning support teachers received the most from STEM Learning Coaches included:
  o Professional learning focused on a variety of hands-on learning experiences (76% of teachers received this type of support),
STEM teaching and learning resources (74% of teachers received this type of support), and

Support in how to use various teaching strategies (60% of teachers received this type of support).

- The professional learning support received the least from STEM Learning Coaches were in the areas of:
  - Career information (18% of teachers received this type of support),
  - Assisting with STEM start-ups (26% of teachers received this type of support),
  - Assessment and evaluation strategies (33% of teachers received this type of support), and
  - Developing success criteria and metrics to assess the effectiveness of the STEM program (33% of teachers received this type of support).

Students’ Perceptions of their Teachers’ Teaching Practice
- The majority of students (over 84%) felt that teachers engaged them in inquiry-based learning practices.
- The least supported area of teacher practice in inquiry-based learning was allowing students to choose their own topics of learning.
- The majority of students (90% elementary and 78% secondary) indicated that teachers engaged them in problem-based learning practices.
- Most students (78% of the secondary school students) felt that STEM education was relevant and meaningful to their life or future career.

Perceptions on Barriers to STEM Implementation
- Administrators believed that a lack of needed resources (funding, equipment, supplies), followed by a lack of teacher content knowledge in STEM disciplines and, to some extent, non-supportive teachers were important barriers to the STEM implementation.
- Teachers felt that the largest barriers were a limited availability of professional learning opportunities, followed by inadequate facilities.
- STEM Learning Coaches felt that the main barriers to the STEM implementation were teacher and administrator perceptions of STEM education as another “fad” that would soon go away, followed by the culture of the school, lack of structured release time for teachers, and lack of support from school administrators.
Eighty percent (80%) of administrators and 73% of teachers felt the STEM Learning Coach model was a very effective or moderately effective model; and that it should be retained and improved.

A discussion of these findings, including the significance for teaching practice, student learning and achievement, and recommendations for future professional learning and scaling up of the TDSB STEM strategy, are discussed in detail in this report.

**FINDINGS AND RECOMMENDATIONS: TEACHING PRACTICE, STUDENT LEARNING AND ACHIEVEMENT, AND TEACHER PROFESSIONAL LEARNING**

**Value of STEM Education**

The results of our study showed that Toronto District School Board (TDSB) administrators and teachers strongly believed in the value of Science, Technology, Engineering, and Mathematics (STEM) education to: 1) develop students with the skills and competencies needed for living in the world; 2) enhance student learning; and 3) help students solve real-world problems. Teachers also strongly believed that implementing a STEM approach in their teaching would improve their teaching practice and nearly all administrators and most teachers indicated that the TDSB STEM strategy should be continued in schools. In terms of the viability and relevance of STEM education as a pedagogical approach, 87% of teachers believed that STEM education would improve their teaching practice. Administrators also saw STEM education as something that was here to stay. Eighty-four percent (84%) of administrators strongly disagreed or disagreed with the statement, “I see STEM as another “fad” that will soon go away”, thus, demonstrating that administrators believed that STEM was not a fad, but an important and long-term approach to education.

The value of using a STEM or Science, Technology, Engineering, Arts, and Mathematics (STEAM) educational approach for student learning is supported by findings in the research literature. For example, students who were exposed to an integrated science, technology, and math curriculum showed improved attendance and achievement scores in math and science (Satchwell & Loepp, 2002). Furthermore, a meta-analysis of seven, multi-year studies conducted between 1992 and 2007 indicated that the Science IDEAS model of integrating Kindergarten to Grade 5 (K-5) science and literacy instruction resulted in improved student achievement in both areas, as measured by national standardized tests (Romance & Vitale, 2012). The value of STEM education for student learning and the overwhelming support by TDSB administrators (98%) and teachers
(82%) for continuing the TDSB STEM strategy suggest that the STEM approach should be continued in existing schools and extended to all schools.

**RECOMMENDATION**
Continue with and expand the STEM strategy to include all TDSB K-12 schools.

**A Transdisciplinary STEM Approach**
An important finding and one that should be addressed is the belief by some administrators and teachers that the STEM transdisciplinary approach can diminish the importance of individual content areas. In fact, 19% of teachers and 26% of administrators strongly agreed or agreed with the statement, “STEM transdisciplinary approach can diminish the importance of individual content areas.” This concern is not unfounded as there is no widespread consensus on how different STEM disciplines should be integrated (Czerniak & Johnson, 2014; Pitt, 2009). Czerniak and Johnson (2014) point out that there is also no common definition of STEM; however, those engaged in STEM reform through the New Media Consortium view STEM “as the integration of subjects used to solve real-world problems” (Czerniak & Johnson, 2014, p. 400). The TDSB is promoting a transdisciplinary approach which differs from an interdisciplinary approach in that a transdisciplinary approach begins with a social issue or real-world problem and draws on knowledge of the disciplines during the problem-solving process to find solutions, whereas an interdisciplinary approach begins with the disciplines and integrates the content to address issues (Meeth, 1978; Quigley & Herro, 2016). A transdisciplinary approach to STEM education goes beyond traditional discipline-oriented subjects and requires more than one discipline to contribute implicitly to understanding an issue.

Within the transdisciplinary approach is, therefore, an implicit expectation that a teacher has background content knowledge of all disciplines in STEM to be able to engage students in using the relevant knowledge and skills from the various disciplines to understand an issue or solve a problem. For elementary school teachers who are mainly generalists and secondary school teachers who are mostly specialists, lack of content knowledge in the different STEM disciplines is a cause for concern (Park & Ertmer, 2008). Additionally, Quigley and Herro (2016) found that middle school math and science teachers had difficulties with transdisciplinary STEM teaching because of their desire to place their content specializations at the forefront. Asghar, Ellington, Rice, Johnson, & Prime, (2012) identified additional barriers to STEM implementation among secondary school math and science teachers such as the organizational and
curricular constraints imposed by compartmentalized disciplinary teaching of subjects and evaluation of students based on disciplinary knowledge.

A strategy proposed to address the issue of teachers’ content knowledge of the different STEM disciplines at the middle school level and which also addresses the concerns raised about diminishing the importance of individual disciplines by participants in the TDSB study is to emphasize “problem-solving using tools of the STEM disciplines, as opposed to education about the content of these disciplines” (Goodwin, Cooper, McCormick, Patton, & Whitehair, 2014, p. 2). As one educator in the Goodwin et al. (2014) study of STEM implementation aptly states, “We aren’t trying to create classrooms full of little mini-engineers. Our goal is to help our students become STEM Thinkers, who know how to solve a wide variety of problems using appropriate tools from science, technology, engineering, and mathematics” (p. 2). Goodwin et al. (2014) recommend that an emphasis on the problem-solving engineering design process (EDP) or some version of it should be included in most STEM curricula. Donna (2012) provides a research-based professional learning (PL) model to promote STEM integration through engineering design activities and demonstrates how engaging in engineering design stages can “promote connections within and across STEM domains” (p. 7).

**RECOMMENDATION**
Incorporate a problem-solving engineering design process to promote a transdisciplinary STEM approach and use concrete applications related to the curriculum to illustrate how the problem-solving design framework draws on content and processes from many STEM disciplines.

**TEACHER KNOWLEDGE OF STEM PEDAGOGY AND RESOURCES**

Overall, teacher participants reported that they had the necessary knowledge and understanding of STEM pedagogy and were aware of the use of various technologies for STEM education.

**Inquiry Learning and Problem-based Learning**
Inquiry- and problem-based practices which involve driving questions, students engaging in investigations, collaboration amongst learners, the use of technology, and the creation of artifacts/products parallel the way scientists work and support curriculum integration (Krajcik & Czerniak, 2014). Furthermore, Bruce-Davis et al. (2014) investigated the teaching practices used in six STEM high schools and found that the most effective strategies and practices to engage students in independent, critical
thinking were through “problem-based learning (PBL), questioning techniques, inquiry-based learning, guided independent research studies, and discussion groups” (p. 295). The results of the TDSB study showed that after participation in the STEM professional learning, most teacher participants (over 90%) reported that they had an understanding of inquiry- and problem-based learning. These results are highly promising and suggest that the TDSB teachers who participated in the pilot TDSB STEM strategy report that they have the foundational pedagogical knowledge and skills to support them in implementing STEM pedagogy in their classrooms.

**Engineering Design Process**

The findings of the study showed that 27% of teachers reported that their understanding of the engineering design process and how to use this strategy to help students develop the various STEM competencies was not fully developed. This finding is similar to other findings in the literature. Avery and Reeve (2013) found that one of the challenges teachers in their study faced was knowledge of authentic engineering design challenges and how engineers solved these real-world problems. A suggestion made by the authors was for “STEM PL developers to provide an exemplar engineering design challenge (EDC) for teachers to use as a reference model” (Recommendation #2: Provide an Exemplar Engineering Design Challenge section, para. 1). However, Capobianco and Rupp (2014) found that even when teachers were provided with specific engineering design examples, their planned design-based lessons and the lessons they implemented in practice did not align. The authors found that teachers concentrated “more of their instructional time on introductory phases such as problem identification and planning. A limited amount of time and attention were given to practices such as testing designs, communicating performance results, and redesigning. This form of direct instruction could be characterized as “domesticating design” in which teachers enforce a more process-oriented, teacher-guided versus conceptually driven, exploratory approach to engineering design-based science instruction” (Capobianco & Rupp, 2014, p. 265).

**RECOMMENDATION**

Provide professional development on engineering design pedagogies that include how engineers approach real-world, authentic design challenges with an emphasis on engineering concepts and principles as well as highlighting content from other STEM disciplines.

An approach to teaching STEM using engineering design does call for PL coaches in a coaching model to have expertise in engineering design. Capobianco and Rupp (2014)
approached this challenge by developing a partnership comprising university engineers and scientists, teacher educators, school teachers, school administrators, and community members where all members contributed to the development of curricular materials and professional learning sessions over the summer to improve teacher knowledge of how to integrate engineering design in science teaching.

**RECOMMENDATION**
Develop community partnerships with STEM discipline specialists, coaches, administrators, and teachers to support the development of STEM content and skills among coaches and teachers and to develop STEM curriculum content based on authentic applications in the real world.

**TDSB STEM Education Resources**
More than half of the teachers (58%) indicated that they had not used the STEM education resources on the TDSB’s STEM K-12 Academic Workspace (AW) Site.

**RECOMMENDATION**
More time needs to be spent during the professional learning activities to explicitly show and demonstrate the utility of the STEM resources available on the TDSB’s STEM K-12 Academic Workspace (AW) site to teachers.

**TEACHER ENGAGEMENT IN PROFESSIONAL LEARNING COMMUNITIES**
Teachers working in collaborative teams to plan and implement STEM pedagogy leads to improved teacher practices, gains in student learning, and builds capacity for STEM teaching (Fulton, Doerrrs, & Britton, 2010; Fulton & Britton, 2011). The results of the TDSB study show that the majority of teachers networked and collaborated with colleagues regarding STEM teaching and co-planned and worked with other colleagues around STEM, suggesting that collaborating in teams was a preferred teacher strategy for STEM planning and implementation. The TDSB findings on teacher STEM Professional Learning Communities (PLCs) contribute to the call by Fulton and Britton (2011) for insights on “the pulse of the ‘naturally occurring [STEM] PLCs’ and their impacts” (p. 13).

Additionally, other studies (Asghar et al., 2012; Roehrig, Moore, Wang, & Park, 2012) have found that STEM PLCs that are interdisciplinary, consisting of teachers from the different STEM disciplines, enabled teachers to develop knowledge of content and pedagogy in other STEM disciplines and also fostered effective STEM integration.
through co-teaching in a single classroom or team teaching in multiple classrooms. Roehrig et al. (2012) also found that giving teacher PLCs flexibility in choosing the level of integration they were comfortable with supported the transition from a disciplinary focus to STEM implementation in their classrooms.

Effective STEM learning teams are characterized by some of the following characteristics (Fulton & Britton, 2011):

- Shared goals: A collaboratively defined understanding of the goals of STEM and what the STEM learning challenge is.
- Leadership support: School leaders gave team members dedicated space and time to meet. This support empowered teachers to make decisions based on student needs.
- Time: School leaders provided teachers with a common time to meet on a regular and sustained basis.
- Examination of student data: A key focus of teacher teams was to work with and modify authentic student data, work samples, and assessments.
- Good facilitation: Good facilitators support the development of knowledge of STEM, resources, and relationships.

**RECOMMENDATION**

Facilitate the formation of in-school or inter-school Professional Learning Communities that consist of interdisciplinary teams of teachers to promote the development of teachers’ disciplinary content and pedagogy, the creation of STEM curricular units, and the co-planning of STEM implementation approaches by:

- School leaders providing dedicated space and time for team meetings.
- Coaches supporting the development of STEM knowledge, STEM resources, and a variety of STEM integration approaches such as co-teaching and team teaching.
TEACHERS’ PERCEPTIONS OF STEM CAREER AWARENESS

The results about teachers’ STEM career awareness is cause for concern as more than one third of teachers did not know where to go to learn more about STEM careers (37%) and nearly one third did not know where to find career resources (32%). As well, 23% of teachers felt that they did not have a strong knowledge of current STEM careers. Research by Hall, Dickerson, Batts, Kauffmann, and Bosse (2011) and Malgwi, Howe, and Burnaby (2005) shows that teachers have a strong influence on students’ consideration of potential careers, and if teacher knowledge of STEM occupations is limited, then this may reduce students’ knowledge and consideration of STEM careers. A lack of teacher knowledge of STEM careers also has implications for teaching practice - these teachers will not be able to show authentic real-world applications of STEM in these fields.

RECOMMENDATION
Provide teachers with information and resources on STEM careers to be able to promote authentic connections in practice and support students with career choices.

TEACHERS’ CURRENT STEM TEACHING PRACTICES

Most TDSB teachers in the study reported that they have tried to develop students’ STEM skills to a great or moderate extent, and that the students have in turn learned STEM skills. However, about one third of the teachers reported that they have not been able to effectively assess students’ STEM skills. Insufficient knowledge around assessment practices when implementing STEM teaching is not uncommon. Avery and Reeve (2013, para 26) reported that teachers in their study experienced challenges with evaluation and assessment, especially evaluating STEM group projects, and teachers expressed the need “to learn how to better assess group projects.” When implementing STEM teaching, some teachers also faced the dilemma of how to integrate authentic assessments with traditional assessments such as tests within a teaching unit (Quigley & Herro, 2016). Quigley and Herro (2016) found that at the end of their transdisciplinary STEM PL with middle school teachers, many had made the transition to embed formative assessments such as peer assessments throughout the unit to understand students’ learning progress. Means, Confrey, House, and Bhanot (2008) additionally recommend performance-based assessment that incorporates technology as an authentic way to assess STEM learning. For example, they suggest digital portfolios to assess projects.
TEACHERS’ CONFIDENCE AND SELF-EFFICACY IN STEM TEACHING

The findings related to teacher self-efficacy were promising, on the one hand, but also suggested that many teachers may still be unsure about how to use STEM pedagogy. While the majority of teachers (84%) reported that they were confident in their ability to teach effectively with a STEM approach, more than one third of teachers (40%) wondered to some degree if they had the necessary skills to teach STEM. These findings are consistent with the literature that calls for sustained engagement in STEM PL over extended periods of time to foster trust and risk-taking with unfamiliar content and pedagogy (Avery & Reeve, 2013).

TEACHERS’ FREQUENCY OF USE OF STEM TEACHING PRACTICES TO DEVELOP STUDENT STEM COMPETENCIES

At the end of the Year One STEM implementation, teachers reported that the most common practices they used to develop STEM competencies were enabling students to use technology to share information, take initiative when confronted with a difficult question, and use technology to support team work and collaboration. The results show that the majority of teachers were supporting students to develop the following 21st century learning competencies (The Partnership for 21st Century Learning, 2015) in their students.

Using Technology as a Tool for Learning and Collaboration Skills
Close to two thirds of teachers had students use technology as a tool for learning all the time or often and just over two thirds of teachers reported that they have students work with others to set goals and have students collaborate to create joint products all the time or often. The use of technology in STEM teaching may be attributed in part to the supportive community developed through the Technology and Learning Fund: Enhanced Supports and Innovation research project (Sinay, 2015; Sinay, 2016) that was
provided to teachers to support meaningful technology integration. When teachers are given opportunities to reflect on their beliefs and share successful practices using technology with colleagues, intrinsic beliefs such as confidence and commitment to technology integration become stronger (Ertmer, Ottenbreit-Leftwich, & York, 2006). The prevalent use of technology by TDSB teachers contributes to the development of 21st century competencies of collaboration, communication, and using computer and digital technologies: skills identified by C21 Canada as requirements to be successful in the workplace and which also contribute to the prosperity of Canada (Brink, n.d.).

Creativity and Innovation Skills
Creativity and innovation skills were developed through the use of a variety of teaching techniques such as having students generate their own ideas to a problem, invent a solution to a complex question, or create an original product to express their ideas. The teaching strategy most frequently used to develop creativity (reported by 77% of teachers) was to have students generate their own ideas about how to confront a problem or question. The strategy used least often was having students create an original product or performance to express their ideas. The latter finding needs to be explored further to find out what factors may be influencing teachers’ less frequent use of students creating original products to express ideas. Two factors emerging in this study that may have an effect are some teachers’ limited knowledge of the engineering design process and strategies for assessing STEM projects.

Self-direction
Self-direction in students was promoted through certain teaching practices. Most teachers (77%) reported that they gave students the opportunity to take initiative when confronted with a challenging problem and allowed students to plan the appropriate steps needed to complete a complex task. However, 50% of teachers reported that they never, rarely, or sometimes had students choose their own topics of learning or questions to pursue.

RECOMMENDATION
STEM Learning Coaches should model to teachers how to provide more opportunities for students to choose their own topics or questions to pursue within the context of curriculum expectations.
**Critical Thinking Skills**

Critical thinking skills were developed by a moderate percentage of teachers using a variety of teaching techniques regularly. This included having students draw their own conclusions based on the analysis of numbers, facts, or relevant information (79% did this often or all the time) and trying to solve complex problems that have no single correct answer (66% did this often or all the time). However, less than two thirds of teachers had students analyze competing arguments, perspectives, or solutions to a problem. This is a disconcerting finding in light of the emphasis in the Ontario science curricula on the science, technology and society and environment (STSE) expectations (Ontario Ministry of Education, 2008) which call for engaging students in resolving issues from different perspectives. The findings of the TDSB study point to the need for more PL on how to analyze issues such as STSE problems to enable more teachers to integrate STSE to develop students’ critical thinking skills.

**RECOMMENDATION**

Incorporate examples of STEM issues that require analysis of competing perspectives or solutions in future PD.

**Global Connections**

Overall, the study findings indicated that global connections were not being fostered to the same degree as the other teaching practices/ student skills. About one third of teachers reported that they never or rarely discussed issues related to global interdependency and slightly more than half of teachers never, rarely, or sometimes enabled students to reflect on how their experiences and local issues connected to global issues. Just as teachers cannot teach in silos, students cannot live in silos. It is important to educate students to understand the interdependency among peoples and countries around global issues such as the environment, poverty, economic growth, financial markets, and technology to enable them to critically reflect and assess the impact of these issues within the broader contemporary world (Mansilla & Gardner, 2007). As well, teachers may not be knowledgeable about the different ways to facilitate global connections with technology or have the technical know-how or support to implement these practices.

**RECOMMENDATION**

Provide examples of how global connections around STEM issues can be made and demonstrate the technology to facilitate global connections in practice in future PD.
TEACHERS’ IMPLEMENTATION OF STEM-RELATED ACTIVITIES AND PROJECTS WITH STUDENTS

The results showed that although teachers used a variety of STEM-related activities, teachers implemented some STEM-related activities and projects more than others. The most popular activities were: hands-on activities (used by 90% of teachers), experiments (used by 67% of teachers), and using computer technology for data collection, analysis, and presentation (used by 64% of teachers). On the other hand, the least used STEM-related activities were: co-op opportunities with business and community partners (used by 3% of teachers), site visits (used by 14% of teachers), and robotics (used by 23% of teachers). Hence, future professional learning should include these least used STEM practices.

RECOMMENDATION
Include support and resources on how to incorporate STEM co-op opportunities, site visits with community organizations, and robotics into STEM teaching and learning.

SUMMARY OF TEACHER PRACTICES

A focus on supporting teachers to learn how to use STEM-related activities such as co-op opportunities with business and community partners, and robotics may also promote the STEM practices least used by teachers such as having students choose their own topics of learning, engage in discussions of global issues, and contribute to joint student projects. For example, a transdisciplinary STEM approach to curriculum using technology, such as robotics, provides opportunities for students to explore their own topics of learning while covering the big ideas in the curriculum. Furthermore, knowledge about technology to facilitate global connections, and community partnerships with universities or other school boards may enhance teacher practices, fostering global connections and global issues.

The results of the Year One TDSB STEM strategy implementation for teacher and student learning suggests that more support needs to be provided to teachers to promote the use of STEM strategies and practices that are underutilized.
STUDENT LEARNING AND ACHIEVEMENT: STEM PRACTICES AND 21ST CENTURY LEARNING SKILLS

Student Perceptions of Teacher Practices
Elementary and secondary school students indicated that the teachers in their school engaged them in inquiry-based learning, project-based learning, collaboration, practices fostering creativity, and technology use.

Inquiry-based Learning
Student data corroborated the finding that the majority of teacher participants in the study have knowledge of inquiry-based and problem-based learning and are implementing these practices in their teaching.

TEACHING AND LEARNING (PEDAGOGICAL) RECOMMENDATIONS
1. Provide teachers with strategies for facilitating open inquiry within the parameters of curriculum expectations.
2. Provide resources on local co-op opportunities and business partners involved in local and global STEM issues (e.g., biotechnology companies, science research labs, hydro companies, mining companies, health sector, space sector, geology sector, technology sector, engineering sector, environmental sector).
3. Illustrate how problem-based learning can be implemented across topics in the secondary school curriculum.
4. Emphasize engineering design pedagogies.

STRUCTURAL (OPERATIONAL) RECOMMENDATIONS
1. Supply robotics kits to all schools.
2. Provide robotics PD to groups of teachers assigned to STEM Learning Coaches.
3. Provide technical training on how to use technologies to facilitate global communication with students in other areas and countries.
4. Provide monetary support (e.g., student transport) for community site visits promoting STEM careers and knowledge in the real world.
As shown in Figure 1, for all but one of the statements on inquiry-based learning, students had at least 84% agreement with the statements that their teachers encouraged them to: (1) ask questions (91% for elementary, 92% for secondary), (2) investigate and explore information (93% for elementary, 93% for secondary), (3) analyze information (86% for elementary, 88% for secondary), and (4) think about what they are learning (91% for elementary and 84% for secondary).

These findings suggest that the elementary and secondary school teachers who participated in the TDSB STEM strategy were becoming more comfortable with the role of the teacher as a facilitator of learning and were using strategies to promote independent student thinking. Research shows that when elementary school students learn science through inquiry-based curriculum modules where teachers received PL sessions and access to coaches throughout the year, there were significant increases in students’ science content knowledge and achievement scores (Banilower, Fulp, & Warren, 2010; Cotabish, Dailey, Robinson, & Hughes., 2013; Granger, Bevis, Saka, & Southerland, 2009).

However, the TDSB results also showed that close to half of students (44% elementary and 47% secondary) felt that their teachers did not allow or seldom allowed them to choose their own topics to learn. This result is not surprising given that teachers in Ontario are accountable to administrators and parents to cover, assess, and report on subject matter content in the Ontario curricula. As such, teachers follow the prescribed
Ontario curriculum expectations and more time is used to cover prescribed expectations, with less focus on opportunities to explore topics that are not directly linked to curriculum expectations. A focus on covering curriculum expectations of individual subject areas, especially in middle and high school, has been identified as a barrier to effective STEM implementation (Asghar et al., 2012; Quigley & Herro, 2016). Teacher focus on individual subject matter content and assessment will remain as long as the structure of subject matter curricula, pedagogy, and assessment remain conceptualized and organized as separate disciplines.

**Problem-based Learning Practices**

The results for two items representative of problem-based learning practices revealed that 90% of elementary school students and 78% of secondary school students agreed with the statement; “in my school, teachers encourage students to work in small groups to find answers to problems”. Additionally, there was 88% agreement among elementary school students and 75% agreement among secondary school students with the statement; “in my school, teachers encourage students to do experiments, build or create things” (see Figure 2).

These overall findings suggest that problem-based learning practices are not as strongly encouraged in secondary schools compared to elementary schools. In fact, 48% of elementary school students strongly agreed that teachers encouraged them to do experiments, build, or create things, compared to 17% of secondary school students. This is an important difference between elementary and secondary school students with respect to problem-based learning practices. Empirical studies show that students engaging in STEM PBL learning, especially low-performing students, achieve higher learning gains. For example, there was higher growth in mathematics scores over three
years among low-performing than high- and middle-performing students (Han, Capraro, & Capraro, 2015) and project-based learning was found to increase Grade 7 and 8 students’ reading and mathematics achievement (Cervantes, Hemmer, & Kouzakanani, 2015). The importance of PBL for students, especially underachievers, suggests that there is a need to encourage and support secondary school teachers to implement more problem-based learning practices.

**RECOMMENDATION**
Support secondary school teachers in designing and implementing problem-based learning practices.

*Collaboration Practices*
Overall, elementary and secondary school students reported very high agreement with all of the statements about collaboration, indicating that teachers were promoting 21st century learning collaboration skills through the STEM implementation.

As shown in Figure 3, there was highest agreement among elementary and secondary school students about the use of collaboration. A driving statement for collaboration was “I am able to work with other students to complete a task” and 93% of elementary school students and 89% of secondary school students strongly agreed, agreed or somewhat agreed with this statement.

*Figure 3: Student Perceptions of Teachers’ Use of Practices fostering Collaboration (somewhat agree, agree, strongly agree)*
Creativity

The TDSB currently nurtures creativity and innovation through many pockets of innovative programs in educational technology (Sinay, 2014; Sinay, Resendes, & Graikinis, 2015). The items measuring practices fostering creativity among students are shown in Figure 4.

Figure 4: Student Perceptions of Teachers’ Use of Practices fostering Creativity (somewhat agree, agree, strongly agree)

![Figure 4: Student Perceptions of Teachers’ Use of Practices fostering Creativity](image)

The results show that both the elementary and secondary school students felt that teachers encouraged them to come up with ideas (92% elementary and 89% secondary). Forty-one percent (41%) of elementary school students and 23% of secondary school students strongly agreed with this statement.

However, for the other three items, more elementary than secondary school students somewhat agreed, agreed, or strongly agreed that they were exposed to teacher practices supporting creativity. When asked whether they were encouraged to “think about new and different ways to solve problems,” 90% of elementary school students compared to 83% of secondary school students said they were in agreement. Similarly, 91% of secondary school students and 84% of elementary school students agreed with the statement that they were encouraged to “find new ways of doing things” and “come up with new and different solutions” (91% of elementary and 81% of secondary school students). As the data show, a large proportion of secondary school students felt that they were not given opportunities to come up with new ideas and different solutions. In fact, 19% of secondary school students strongly disagreed, disagreed, or somewhat disagreed with the statement, “I am able to come up with new and different solutions.” This was the highest percentage of disagreement among all the questions asking about
student abilities among secondary school students. In comparison, only 9% of elementary school students felt that they were unable to come up with new and different solutions.

Teachers play a significant role in nurturing students’ creativity and innovative thinking and the importance of employing innovative teaching to increase students’ creativity has been acknowledged in the literature (Ayverdi, Asker, Öz Aydın, & Sarıtaş, 2012; Beghetto, 2007; Esquivel, 1995; National Advisory Committee on Creative and Cultural Education [NACCCE], 1999; Sharp, 2004; Simplicio, 2000). These findings suggest that more secondary school teachers should be encouraged to use the STEM practices that foster creativity among students.

**RECOMMENDATION**
Incorporate and model practices fostering creativity in students in PD sessions for secondary school teachers.

**Use of Technology**
With regard to how technology is used for learning, elementary and secondary school students had similar viewpoints on teacher practices and technology. Students felt that teachers encouraged them to use technology to explore information (85% of elementary school students and 88% of secondary school students strongly agreed, agreed, or somewhat agreed). On the other hand, elementary and secondary school students felt that teachers were not as encouraging when it came to using technology to share information with others. This is illustrated by the finding that 31% of elementary school students and 24% of secondary school students strongly disagreed, disagreed, or somewhat disagreed with the statement that “teachers encourage students to use technology to share information with others.” The latter result suggests that teachers need professional learning support on how to implement practices that enable students to use technology to share information with others.

**RECOMMENDATION**
Provide PD to demonstrate how to implement practices that enable students to use technology to share information with others.
Global Learning

Students were asked three different statements about global learning, as shown in Figure 5. Student responses to two of these statements elicited different results among elementary and secondary school students. The statements asked students whether they were encouraged to (1) “do research about different places and cultures around the world” and (2) “discuss topics and issues in our world.” There was strong agreement among elementary school students with these statements, with at least 80% agreement; while secondary school students had much less agreement, in the range of 64-69%. As well, students, both at the elementary and secondary school levels, felt strongly that in their school, teachers did not encourage them to connect with students in different parts of the world. Only 49% of elementary school students and 34% of secondary school students strongly agreed, agreed, or somewhat agreed with this statement.

The fairly low use of global learning strategies as reported by students is consistent with teacher reports of their integration of global education in practice, as previously noted. These findings are not unexpected in view of similar reports from studies conducted in the Toronto area where teachers cited “lack of time and the fact that global education at the elementary school level was not a top priority, particularly in light of heightened expectations for literacy and numeracy” (Mundy & Manion, 2014, p. 33). The lack of a provincial global curricular framework also leaves the onus of interpreting curriculum expectations on teachers, resulting in fewer teachers opting to do this. For example, in a study of Ontario teachers, it was a select group of secondary school teachers in Ontario schools, highly invested in global education and with prior knowledge of global education, who chose to integrate global education into their discipline based classroom practices (Schweisfurth, 2006). To promote widespread implementation of global education, teachers need to learn how to interpret existing curricula to infuse global learning into classroom practice.
Figure 5: Student Perceptions of Teachers’ Global Learning Practices
(somewhat agree, agree, strongly agree)

RECOMMENDATION
Provide teachers more technology and pedagogy support on how to interpret curricular expectations to promote global learning in the classroom, especially in secondary school classrooms.

**STEM Skills and 21st Century Learning Competencies**

Twenty-first century competencies such as creativity and innovation, critical thinking, collaboration, effective communication, building character, culture and ethical citizenship, and comfort with technology have been identified as essential for work in society (C21 Canada, 2012).

Overall, students at the elementary and secondary school levels showed very high agreement with the statements on STEM skills and competencies. For elementary school students, overall agreement ranged from 84-93% among the 11 statements, and for secondary school students, overall agreement ranged from 79-95%. These findings indicate that elementary and secondary school students expressed confidence about 21st century learning skills. For example, students both at the elementary (93%) and secondary school levels (95%) strongly agreed, agreed, or somewhat agreed that they could respect the differences of their peers. However, elementary and secondary school students also revealed that they sometimes struggled with time management. For example, 16% of elementary school students strongly disagreed, disagreed, or somewhat disagreed with the statement, “When I have a lot of homework, I can choose what needs to be done first” and 21% of secondary school students showed the highest
levels of disagreement with the statement, “I am confident I can manage my time wisely when working on my own.”

**RECOMMENDATION**
Students at both the elementary and secondary school levels need support to develop their time management skills.

**Student Perceptions of the Relevance of STEM and Impact on Learning**
Seventy-eight percent (78%) of secondary school students strongly agreed, agreed, or somewhat agreed that STEM education was relevant and meaningful to their lives. Demonstrating to students the relevance of STEM education to their lives or future careers is important in light of the growing number of jobs at all levels that will require STEM knowledge (Lacey & Wright, 2009; National Research Council, 2011).

Secondary school students were also asked to what extent STEM education improved their learning. A large percentage of students felt that STEM education improved their learning, but surprisingly, almost 30% of students said they were not sure. The large percentage of students who were not sure suggests that more work needs to be done by teachers to make explicit the relationships between STEM practices and learning.

**STEM IMPLEMENTATION**

**Support Received from STEM Learning Coaches**
The STEM activities implemented by teachers the most were consistent with the PL support received from STEM Learning Coaches. The most popular support teachers indicated receiving from coaches was professional learning focused on a variety of hands-on learning experiences (76% of teachers received this type of support). In addition, over 90% of teachers reported that they had implemented hands-on STEM learning with their students. As well, teachers indicated that they received support in regards to STEM teaching and learning resources (74% of teachers received this type of support) and support in using various teaching strategies (60% of teachers received this type of support). These findings reinforce the importance of having STEM Learning Coaches to help teachers make the transition from STEM theory to STEM classroom practice and are consistent with the review by Cornett and Knight (2008) about the beneficial effects of sustained coaching to raise the rate of classroom implementation or skill transfer and positively impact teachers’ sense of self-efficacy.
However, teachers felt that they received little or no support from STEM Learning Coaches in the areas of career information (18% of teachers received this type of support), assisting with STEM start-ups (26% of teachers received this type of support), assessment and evaluation strategies (33% of teachers received this type of support), and developing success criteria and metrics to assess the effectiveness of the STEM program (33% of teachers received this type of support). Some of these areas were also noted by administrators. Administrators indicated that they received the least support in the areas of career information, STEM start-ups, and success criteria and metrics to assess the effectiveness of the STEM program.

**Effectiveness of STEM Learning Coaches**

Teachers felt that the STEM Learning Coaches were most effective in the following areas: (1) providing STEM teaching and learning resources (64% effective; 26% somewhat effective), (2) participating in or running the STEM showcase (58% effective; 33% somewhat effective), and (3) providing professional learning focused on a variety of hands-on learning experiences (55% effective; 37% somewhat effective). The areas where teachers felt that coaches were least effective were consistent in some cases with the areas where coaches provided the least support: providing career support, assisting with STEM start-ups, and setting goals to move along the STEM continuum.

Overall, close to two thirds of teachers (63%) and nearly three-quarters of administrators (71%) rated the quality of support received from the STEM Learning Coaches as excellent or very good. Additionally, 14% of administrators and 13% of teachers rated the coaches as fair, suggesting both administrator and teacher satisfaction with the professional and coaching support.
Effectiveness of the STEM Learning Coaches Model
Eighty percent (80%) of administrators and 73% of teachers viewed the STEM Learning Coach model as a very effective or moderately effective model. Sixty-eight percent (68%) of teachers felt that the coaching had a great or moderate impact on their understanding of STEM and 62% of teachers felt that the coaching had a great or moderate impact on their capacity to implement STEM. Those teachers and administrators who reported that the STEM Learning Coach model was slightly effective or not at all effective were asked what other models of coaching they would suggest. Overwhelmingly, their responses indicated that the coaching model strategy should be retained, but that it should be improved.

RECOMMENDATIONS
1. Increase the number of STEM Learning Coaches who can be made available to teachers.
2. Have STEM Learning Coaches at the school site more frequently for consistent access.
3. Have STEM Learning Coaches as part of the staff.

The need to provide STEM Learning Coaches with more comprehensive STEM knowledge was consistent with feedback from all of the 10 coaches who reported that they provided the least support in (1) developing success criteria and metrics to assess the effectiveness of the STEM program, (2) providing career information, and (3) providing assessment and evaluation strategies.

Challenges and Barriers to the STEM Implementation
Administrators and teachers identified time as the greatest challenge (e.g., timetable constraints, not having enough release time for planning, and not having enough classroom time for STEM activities). Additional challenges identified were the lack of financial resources, insufficient professional learning opportunities, lack of teacher confidence, and resistance to change.

Specific barriers to the STEM implementation identified by administration were a lack of needed resources (funding, equipment, supplies), followed by a lack of teacher content knowledge in STEM disciplines and, to some extent, non-supportive teachers. Teachers felt that the largest barriers to the STEM implementation were a limited availability of
professional learning opportunities, followed by inadequate facilities. Teacher’s prior beliefs and low levels of content knowledge have also been identified in the literature as barriers that reduce the effectiveness of STEM implementation (Asghar et al., 2012).

The majority of teachers (73%) also indicated that leadership support from principals was not a barrier to the STEM implementation, suggesting that principal support was available for teachers. However, STEM Learning Coaches felt that some barriers to STEM implementation were teacher and administrator attitudes to STEM as being another “fad” and lack of leadership and support from the school principal. Leadership support by the principal for coaching has been identified as an important factor for effective PL implementation (Sumner, 2011).

RECOMMENDATIONS

• Teachers need to have continued and consistent access to STEM Learning Coaches.
• More time needs to be allocated for planning and collaboration with teachers and coaches.
• It is necessary to have more resources (i.e., unit plans, technology, and activities).
• Teachers need to have more examples of best practices/teaching strategies for STEM.
• There needs to be more professional learning opportunities (indicated by teachers, and not administrators, this was one of the differences in results).
• Teachers need time to observe others teaching STEM (indicated by teachers, and not administrators, this was one of the differences in results).
• It is important to have more partnerships, school to school and between schools and outside organizations (indicated by administrators, and not teachers, this was one of the differences in results).
• There is need for a strong relationship and understanding between the STEM Learning Coach and administrator to determine what the school needs and where they are heading in regards to STEM.
• Principal support of structural changes (e.g., timetabling, room allocation) is essential.

Recommendations for Scaling up the STEM Implementation

The findings from the Year One implementation suggests that the coaching model is a highly viable model to promote STEM professional learning in schools and that it needs to be improved in certain areas to enhance its effectiveness. Such improvements will also be needed to scale up the STEM implementation across the school board.
SECTION I: STEM TEACHING AND LEARNING IN THE TDSB

Increasing society’s capacity for innovation is essential to a nation’s prosperity and productivity (Homer-Dixon, 2000). The Organisation for Economic Co-operation and Development (OECD) (2010) describes innovation as a dynamic, interdisciplinary, and collective process that has a direct impact on the economic and social aspects of society. In modern societies, innovation is driven to a great extent by advances in science, technology, engineering, and mathematics (STEM) (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011).

Since advances in STEM drive innovation, a growing number of jobs at all levels will require STEM knowledge (Lacey & Wright, 2009). It is increasingly important that the general public, and not just those who reach post-secondary education, possess at least basic literacy in STEM fields (Krishnamurthi, Ballard, & Noam, 2014). However, while developing societal proficiency in STEM fields is important, it is “not sufficient” for innovation, which also requires a host of “complementary skills”- popularly known in education as “21st century competencies” - such as creativity, the ability to communicate and collaborate, and so on (Council of Canadian Academies, 2015, p. xv). While Canada boasts to be one of the most educated populations in the world (OECD, 2014), we have maintained a weak international record on innovation and productivity.

RECOMMENDATIONS
1. Hire more STEM Learning Coaches to support smaller groups of teachers in the same school or clusters of schools (As the literature suggests, effectiveness of coaching decreases with more than 12 teachers).
2. Hire STEM Learning Coaches who are preferably teaching at a participating school to provide for frequent and consistent on-site presence.
3. Designate coaches to a group of schools in the same area as their home school to facilitate consistent on-site access.
4. Provide comprehensive STEM training for STEM Learning Coaches through a TDSB coaching orientation that includes determining success criteria and metrics for assessing STEM programs, STEM assessment/evaluation strategies, and STEM career information.
5. Provide STEM Learning Coaches with opportunities to build specialized content knowledge of the STEM areas through online modules, webinars or free online training courses such as those offered by NASA. NASA offers certificate programs for K-12 teachers in robotics, statistics, project-based inquiry learning, and technology integration and self-directed courses in astrobiology, microgravity, and outer space environment.
when compared with other industrialized nations (World Economic Forum, 2013). Also, although recent research discredits suggestions that Canada is lacking in STEM skills nationally (Council of Canadian Academies, 2015), the data continue to show that women and Indigenous peoples remain under-represented in STEM fields (Hango, 2013; WISEatlantic Research Group, 2014).

As declared in the Council of Canadian Academies (2015), in order “to build [STEM] capacity and to maximize Canada’s potential for innovation, evidence points to the value of early childhood interventions to strengthen fundamental skills” (p. xiv). Developing effective and scalable STEM education programs that can be applied across K-12 settings is an educational imperative needed to help students develop the critical competencies and skills they will need to be productive contributors in a knowledge-based society (National Research Council, 2011). As such, TDSB has begun developing a STEM strategy that will hopefully be scalable for educational programs at all levels. This research examines the TDSB’s K-12 STEM strategy.

Research is needed to help pinpoint those practices and conditions that are having the most impact on teacher practice and student learning and achievement. To this end, ongoing program evaluation is integrated into the implementation plan and STEM program objectives. This research assessed the application of the TDSB STEM strategy in its pilot STEM lead schools to begin to track preliminary outcomes for teachers and students engaged in the program over three years. Results from the first year of implementation served as a baseline from which to assess changes in subsequent years of implementation. The data will be used by the STEM leadership team to make informed decisions regarding the best processes and strategies for implementing STEM teaching and learning across the system.

**TDSB’s K-12 STEM Strategy: Vision, Goals, and Objectives**

In September 2014, the TDSB began an initiative to implement STEM education in 60 pilot schools as part of its system-wide K-12 STEM Strategy (see Figure 6). The goal is to have all schools in the board “incorporate STEM programming [in order to] provid[e] students with opportunities to apply their knowledge and skills within the context of meaningful and complex real world problems” (TDSB, 2014a, p.13). The TDSB’s K-12 STEM strategy is “a transdisciplinary approach to inquiry and problem-based learning...to foster collaboration, creativity, and innovation to prepare students to participate in a rapidly changing, technological and interconnected world” (TDSB, 2014b, para. 1).
The TDSB aims to scale up the STEM program throughout the Board as part of the TDSB’s Vision for Learning and Action Plans.\(^2\)

The TDSB’s K-12 STEM Strategy is guided by the TDSB’s five Strategic Directions (TDSB, 2015b):

- Make every school an effective school
- Build leadership within a culture of adaptability, openness and resilience
- Form strong and effective relationships and partnerships
- Build environmentally sustainable schools that inspire teaching and learning
- Identify disadvantage and intervene effectively. (para. 2)\(^3\)

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\(^2\) For further information on the TDSB’s Vision for Learning and Action Plans 2013-2017, please visit: [http://www.tdsb.on.ca/AboutUs/DirectorofEducation.aspx](http://www.tdsb.on.ca/AboutUs/DirectorofEducation.aspx)

\(^3\) For further information on 2014-2015 TDSB Board Improvement Plan for Student Achievement K-Grade 12+, please visit: [http://www.tdsb.on.ca/Portals/0/BIPA%20TDSB%202014-15%20Final.pdf](http://www.tdsb.on.ca/Portals/0/BIPA%20TDSB%202014-15%20Final.pdf)
The vision for the TDSB’s K-12 STEM Strategy (TDSB, 2015a) is to continue to:

- Provide STEM education for all students
- Move away from teaching subjects in silos and linking real world issues to classroom teaching and learning
- Promote problem-based learning and STEM skills to allow students to stay current, explore, inquire, and actively engage in relevant issues of the world around them
- Encourage scientific discovery and technological innovation to shape how future citizens work collaboratively to provide creative and viable solutions to today’s and tomorrows’ real-life problems (para. 2).

The TDSB is dedicated to fulfilling four major commitments through the STEM program (TDSB, 2014b):

- Investment in STEM instructional leadership
- Purposeful and targeted STEM resources
- Student choice
- Strong and effective community partnership. (p.12)

The TDSB STEM Strategy goals are to (TDSB, 2015a):

- Promote higher levels of student achievement by supporting all entry points for a STEM-centric pedagogy in all TDSB schools and for a range of career pathways.
- Develop students’ creative and innovative thinking in and across disciplines, with a focus on the application of mathematics, science, engineering design, and technology.
- Increase students’ confidence and engagement in dealing with open-ended and complex problems.
- Challenge the under-representation of historically marginalized communities in STEM fields by removing existing barriers to engagement and achievement. (p. 1)
In addition to these major goals, the STEM program is guided by 10 major criteria that were drawn out to help ensure success (TDSB, 2014a):

1. Problem-based learning integrated in a transdisciplinary approach
2. Integration of e-Learning and blended technology
3. Authentic assessment and evaluation of STEM skills and behaviours
4. Authentic displays and exhibits of STEM skills, behaviours, and products
5. In-school and out-of-school STEM programs, competitions, events, kits, etc.
6. Support and focus on under-represented, economically, or otherwise disadvantaged students
7. Professional development on STEM integration, implementation, curriculum, lessons, activities, etc.
8. STEM-related mentorship, site visits, and partnership opportunities with business and community partners
9. STEM-related co-op placements, internship, and work-based learning opportunities
10. STEM-related connections with post-secondary institutions, or research centres (pp. 19-21)
Figure 7 displays the TDSB’s K-12 STEM Strategy Mission, Vision and Commitments.

**Figure 7: TDSB K-12 STEM Strategy Mission, Vision, and Commitments**

**Mission**
To introduce STEM – a trans-disciplinary approach to inquiry and problem-based learning – across the TDSB to foster collaboration, creativity and innovation to prepare students to participate in a rapidly changing, technological and interconnected world.

**TDSB’s Vision**
- Providing STEM education for all students.
- Moving away from teaching subjects in silos and linking real world issues to classroom teaching and learning.
- Promoting problem-based learning and STEM skills to allow students to stay current, explore, inquire and actively engage in relevant issues of the world around them.
- Encouraging scientific discovery and technological innovation to shape how future citizens work collaboratively to provide creative and viable solutions to today’s and tomorrow’s real-life problems.

**TDSB’s Commitments**

<table>
<thead>
<tr>
<th>Investing in STEM Instructional Leadership</th>
<th>Providing Purposeful and Targeted STEM Resources</th>
<th>Supporting Student Choice</th>
<th>Building Strong and Effective Community Partnerships</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Add 10 STEM learning coaches to support targeted lead schools</td>
<td>- Provide STEM kits to pilot schools to facilitate planning, development and implementation of STEM programming</td>
<td>- Encourage opportunities for students to collaborate, innovate and create</td>
<td>- Build STEM-related connections with post-secondary institutions</td>
</tr>
<tr>
<td>- Develop foundational core in mathematics and science</td>
<td>- Provide interactive probeware and software to be used</td>
<td>- Engage students through relevant and contextualized problem-based learning</td>
<td>- Offer career exploration in STEM related fields with mentorship and co-op opportunities with business and community partners</td>
</tr>
<tr>
<td>- Collaborate among different disciplines to deliver relevant STEM programming</td>
<td>- Create STEM monographs to align connections with various disciplines</td>
<td>- Support co-curricular robotics competition</td>
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**Source:** TDSB. (2014b)
SECTION II: WHAT THE RESEARCH SAYS

As this report will show, the goals and criteria of the TDSB STEM strategy embody the best practices of STEM programming as described in the literature. In what follows, we explore a number of these themes in greater detail, highlighting the aspects of each that align most effectively with STEM education.

STEM education is a concept that has been used in educational circles for over 20 years (Sanders, 2008). However, the term remains ambiguous and open to interpretation of stakeholders (Sanders, 2008; 2012). Practical applications of STEM initiatives also vary both in regard to implementation methods as well as efficacy. For example, one of the most notable trends to emerge from the research is the tendency for math and science to be emphasized, and work in technology and engineering to remain under-represented, especially at the K-8 level (Bybee, 2010). Reasons for this are varied, and include the lack of quality curricular materials and professional learning opportunities in these areas (Kimmel, Carpinelli, Burr-Alexander, & Rockland, 2006), insufficient education and experience on the part of teachers in these disciplines (Epstein & Miller, 2011), and low confidence in teaching STEM subjects (Nadelson, Callahan, Pyke, Hay, Dance, & Pfiester, 2013). As a result, in more recent literature, STEM advocates are promoting conceptual frameworks that emphasize the integration of STEM subjects with a focus on 21st century competencies. For example, Sanders (2008) introduced the concept of “integrative STEM education” with the following definition:

Integrative STEM education refers to technological/ engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with the concepts practices of technology and engineering education (p. 2).

The Hanover Research report *Best Practices in Elementary STEM Programs* (2011) describes STEM education as an initiative that seeks to help students develop core knowledge in the four main disciplines, while also cultivating “soft skills” such as problem solving, critical thinking, and inquiry (p. 7). The TDSB takes a slightly different approach, adopting a definition of STEM education as “a transdisciplinary approach to inquiry and problem-based learning that fosters collaboration, creativity and innovation in all students” (TDSB 2015c, para. 1). A transdisciplinary approach

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4 To elaborate briefly on this second point, Epstein & Miller (2011) highlight a 2000 study conducted by the National Survey of Science and Mathematics Education which found that the majority of K-5 teachers who took part in the study did not feel adequately qualified to teach science (p. 12) and almost one quarter did not have any postsecondary coursework in science education at all (p. 11).
emphasizes work that goes beyond disciplinary boundaries to seek new combinations of ideas, information, or disciplinary concepts, with the ultimate goal being to understand the present world (Nicolescu, 1999).

With this particular vision in mind, this report explores five key issues around the effective development and implementation of STEM education. First, we outline key elements of the TDSB’s STEM implementation plan, including program components and processes. We follow this by elaborating on the concept of STEM education as adopted in this research with a focus on the implications of a transdisciplinary approach. Next, we discuss the pedagogical models best suited for this enterprise. We go on to discuss robotics and STEM education, followed by professional learning models for STEM education, with a focus on exploring the role of coaches and facilitators in building STEM capacity within and across schools.

**TRANSDISCIPLINARY STEM EDUCATION**

The TDSB views STEM education as “[a] transdisciplinary approach to inquiry and problem-based learning that fosters collaboration, creativity, and innovation in all students” (TDSB, 2015a, para. 1) “while integrating the content and skills of the various disciplines” (TDSB, 2014a, p.13). An integrative approach is necessary for “transdisciplinary” efforts, where there is an emphasis on creative knowledge construction and innovation that both cuts across and transcends disciplinary boundaries (Nicolescu, 1999). As described by the Holistic Education Network, a transdisciplinary approach “involves multiple disciplines and the space between the disciplines with the possibility of new perspectives 'beyond' those disciplines (2011, para 2). Nicolescu (2010) describes “transdisciplinary” as “that which is at once between the disciplines, across the different disciplines, and beyond all disciplines” (p. 22).

As Figure 8 illustrates, a transdisciplinary approach utilizes strengths, practices, and ideas from across different disciplines, but is concerned with innovation and the creation of new knowledge. To be engaged in a transdisciplinary effort requires what Gardner (2007) calls the “synthesizing mind” which calls for "the ability to knit together information from disparate sources into a coherent whole” (p. 46) and make coherent disparate bits of information and knowledge (Gardner, 2007). Transdisciplinary teams work on shared problems using a common conceptual framework that draws together discipline-specific ideas, concepts, and approaches, but transcends those perspectives to explore whole systems and to create new and innovative solutions (Choi & Pak, 2006). As Nicolescu (1999) points out, a transdisciplinary venture “entails both a new
vision and a lived experience” and engages creative capacities in order “to understan[d] the present world” (Nicolescu, 2010, p. 22). This view is in alignment with the TDSB’s vision of STEM education, which views it as “grounded in experiential inquiry” and intended to provide students with opportunities to “investigate possible solutions to complex, real-world problems (those with civic, health, financial, environmental, local and global implications) by applying the knowledge, skills and behaviours of science, technology, engineering and mathematics (STEM)” (TDSB, 2014b, p.27) and that provides an opportunity to engage new and innovative pedagogical approaches and ideas to develop a coherent STEM framework that can be both scalable and robust. Figure 8 explains the different levels of STEM integration.
A transdisciplinary STEM approach can be distinguished from an interdisciplinary (cf. Morrison, 2006), or multidisciplinary perspective (cf. Green & Anid, 2013; Zhe, Doverspike, Zhao, Lam, & Menzemer, 2010). A multidisciplinary approach can be explained as one that "draws on knowledge from different disciplines but stays within the boundaries of those fields" (Natural Sciences and Engineering Research Council of Canada [NSERC], 2004, p. 353). In terms of teamwork, multidisciplinary groups work together on a common problem, but members remain grounded in their own disciplinary base (Choi & Pak, 2006). An interdisciplinary approach takes different disciplines and juxtaposes ideas and concepts from each area, focusing on the intersections between fields of study (Choi & Pak, 2006). Interdisciplinary efforts can even give rise to new disciplines (Nicolescu, 2010); however, while interdisciplinary
teams work jointly to reach a common goal, they remain rooted in a discipline-specific base (Choi & Pak, 2006).

A transdisciplinary approach emphasizes the integration of disciplinary practice and values, and can help provide a coherent framework for STEM instruction (see Sanders, 2012). For example, in science, as in math and engineering, asking deep questions, creative problem solving, and finding the most coherent explanations or solutions to problems go to the heart of each discipline (Bereiter & Scardamalia, 2012; Katehi, Pearson, & Feder, 2009; Rockland, Bloom, Carpenelli, Burr-Alexander, Hirsch, & Kimmel, 2010). Effective applications of technology in these fields are bound up with these practices; with common design principles driving advances in technology as well (Sanders, 2012).

Morrison (2006) provides an overview of key STEM competencies that fit with an integrated approach. According to this framework, STEM education ought to foster students’ abilities in the following areas:

**Problem-solving:** including the ability to define questions and identify problems; design investigations and experiments to gather and test data; plan strategies to collect and organize data; draw conclusions, and apply understandings to new situations and contexts.

**Innovation:** the creative use of concepts and principles from each major discipline and the ability to apply them to design processes.

**Inventiveness:** the ability to identify an authentic need or real world problem, and engage in an iterative design process to work out and implement solutions (design, test, redesign, etc.).

**Self-reliance:** the ability to take initiative to set agendas, plan next steps, develop time management skills, gain self-confidence, and direct students’ own learning.

**Logical thinking:** the capacity to exercise and apply disciplinary habits of mind and thought processes of science, mathematics, and engineering to the processes of innovation and invention. This includes students developing the capacities for self-regulation (metacognition, goal-setting, and so on).

**Technological facility:** which includes both understanding the nature of technology, as well as skill in use and application.
From a transdisciplinary perspective, integrating discipline-based concepts and ideas within shared practices and values may even extend beyond STEM domains and could be enhanced through further incorporation with other subjects such as the arts, social studies, and so on (Sanders & Wells, 2006). Advocates of “STEAM education,” for example, emphasize the role of the arts in science, engineering, technology, and math (e.g., Sinay & Jaipal-Jamani, 2016). A transdisciplinary approach provides a framework for understanding how a wide range of disciplinary expertise can be engaged in a coherent enterprise. However, a STEM transdisciplinary approach requires curricula to be transdisciplinary too and in Ontario, currently, we have discipline-based curricula so this could be one of the limitations of implementing such an approach in schools. We will discuss this in detail based on the findings of our research study on the first year implementation of the TDSB STEM strategy.

**PEDAGOGICAL APPROACHES FOR A TRANSDISCIPLINARY STEM EDUCATION**

Instructional approaches that are best suited for a transdisciplinary approach to STEM education are those that nurture capacities for innovation, creativity, and problem-solving and also engender an equitable learning environment that activates student engagement and confidence, and helps all students to achieve. As argued by Krishnamurthi et al., (2014), “in order for children to begin to see themselves as scientists, engineers, and mathematicians, they need to develop a sense of self-confidence in these areas, and perceive themselves as legitimate contributors in a STEM enterprise” (p. 8). Students also perform better when they can actively engage in science and when they see it as personally meaningful and relevant to their current and future lives (Lee, 2011).

Accordingly, inquiry-based learning approaches such as problem-based learning (Barrows, 1996) or challenge-based learning (Johnson & Adams, 2011) have all been recommended in the literature as appropriate models for STEM education (Bransford, Vye, & Bateman, 2002). These models aim to activate student engagement and curiosity; encourage work around authentic, real-world problems; honour student choice and voice; stress collaboration; focus on big disciplinary ideas; and emphasize metacognition and reflection as integral components of learning and building knowledge (Friesen & Scott, 2013). Two pedagogical approaches that share theoretical roots with these models, but are distinct in their emphasis on innovation, design, and knowledge creation are "Knowledge Building," and “Design Thinking”.
Knowledge Building is both a theory and a pedagogical approach that represents a “coherent effort to initiate learners into a knowledge creating civilization and help them find a place in it” (Scardamalia & Bereiter, 2006, p. 97). It can be described in its most general sense as “giving students collective responsibility for idea improvement” (Scardamalia & Bereiter, 2003, p. 12). From a Knowledge Building perspective, authentic, creative work with knowledge can begin at the earliest grade levels, helping to set “students on a developmental trajectory that stretches from the inherent curiosity of children to the ‘disciplined creativity’ characteristic of experts and competent knowledge creators” (Scardamalia & Bereiter, 2003, p. 1370; as cited in Resendes, 2014, p. 24). Knowledge Building is not a set of procedures, but is a principles-based pedagogy that is grounded in 12 foundational principles that are known to be drivers of innovation, creativity, and knowledge creation (Scardamalia, 2002). They include tenets such as “idea improvement,” “community knowledge”, “collective responsibility,” and “democratizing knowledge,” among others (Scardamalia, 2002). The principles can serve as pedagogical guides or bases for evaluating practice. Knowledge Building pedagogy is adaptable to different domains and individual needs, and provides a promising approach for implementing a vision of STEM education that emphasizes innovation and advancement of community knowledge. In a study reporting findings from a recent “pre-pilot” project that involved TDSB educators and students in Knowledge Building, there were reported improvement in students' collaboration, creativity and innovation skills, especially in “fostering community” (Sinay, Douglin, & Alam, 2014).

Design thinking, on the other hand, is a methodology used for creative problem-solving. The MaRS Discovery District defines design thinking as “a mindset and a methodology used to better understand problems and implement creative solutions” (MaRS, 2014). This model of thinking was first described by David Kelley, co-founder of the world-renowned design firm IDEO and further developed out of the d.school, the Institute of Design at Stanford University, beginning around 2004.

Design thinking emphasizes creative problem-solving, engages multiple modes of engagement and learning styles, collaborative work with ideas, and encourages self-assessment by immersing students in authentic design processes and practices (MaRS, 2014). The design thinking process can be articulated as a series of phases, beginning with discovery, interpretation, ideation, experimentation, and evolution (IDEO, n.d., p. 15). Design thinking has been identified as an effective and motivating way to engage students in STEM education in ways that also encourage innovation, creativity and student-led learning (Knowledge without Borders, 2014). Both Knowledge Building and
design thinking fit with the TDSB’s transdisciplinary approach to STEM education in an effort to deepen student understanding.

**COMMUNITY CONNECTIONS**

Research shows that building networks and relationships between classrooms, parents, community members, and local businesses or organizations can help to build both teacher and student capacity in STEM teaching and learning (Hanover Research, 2011). For instance, The National Commission on Teaching and America’s Future (NCTAF) ran a STEM project initiative from 2009-14 in which teachers from across disciplines came together to design project-based STEM learning experiences for their students in collaboration with scientists and engineers from partnering organizations. As described in their project report, the STEM groups shared “the core competencies of trust, collaboration, and shared accountability for student achievement critical to all successful teams” (Fulton & Britton, 2011, p. 17). The STEM learning teams in this project were intentionally cross-curricular and brought together science, math, and technology teachers to collaborate on ways to improve their STEM teaching and to build on the connections that crossed their respective content areas. These teams also included experts in the STEM fields who worked together with teachers to design and implement project-based learning activities that targeted desired achievement outcomes, as identified by the teacher teams. Teachers found the opportunity to work in these hybrid teams very valuable, while the majority of students who participated in the program reported that the projects were engaging and meaningful, and helped them to better understand the world around them (Fulton & Britton, 2011). It is important to note that the research showed the importance of building community and that matters such as performance appraisals, compensation, and individual incentive systems can be a detriment to 21st century learning (Fulton & Britton, 2011).

Extra-curricular programs, supported by community partnerships, can play a role in helping students, particularly those from under-represented groups, to broaden their ideas and interest in STEM careers (Krishnamurthi et al., 2014). There is a lot of research that advocates for extra-curricular activities and this research suggests that structured learning time in a more informal environment gives learners opportunities for positive interaction, chances to take initiative, be challenged, and develop new skills and talents (American Youth Policy Forum, 2006; Durlak & Weissberg, 2007; National Research Council and Institute of Medicine, 2002). For instance, Techbridge is an after-school and summer program that focuses on engaging girls in STEM career exploration. A key component of the program is the use of STEM professionals as role models. Findings
from research into the program showed that students’ perceptions and ideas about STEM careers and the people that work in them were expanded due to participation in the program (Krishnamurthi et al., 2014). Findings revealed that 94% of participants stated that they knew more about different kinds of STEM-related jobs, and 81% of girls said that their engagement with role models and participation in field trips increased their interest in working with technology, science or engineering (Krishnamurthi et al., 2014).

This is particularly important considering that students actually form ideas and interests in STEM identities and careers as early as elementary school and it is beginning at this young age that students begin to form ideas about whether or not they will or cannot excel in STEM subjects (President’s Council of Advisors on Science and Technology [PCAST], 2010). Exposing students to STEM subjects repeatedly and beginning at an early age can help them develop future interest and aptitude in these areas (Hanover Research, 2011). An influential study by Tai and colleagues (2006) showed that an early interest in STEM careers can be a better predictor of whether students will pursue such careers after high school than academic achievement. In this study, students who were average achievers in math, but who demonstrated an early interest in pursuing physical science or engineering careers were more likely to follow through on those interests in comparison to students who did not express this interest, but demonstrated higher achievement in math (Tai, Liu, Maltese, & Fan, 2006).

Additionally, in the study on extra-curricular activities conducted by the National Research Council, *Learning Science in Informal Environments* demonstrated the importance of extra-curricular activities for learners to experience excitement, interest and motivation to learn that can be better fostered in a more informal setting (Bell, Lewenstein, Shouse, & Feder, 2009).

As these studies demonstrate, engaging STEM experts and fostering relationships with community partners can support the objective to engage and stimulate the interest of more students in STEM. The research shows that by providing students varied opportunities to expand their perceptions of: (1) who is involved in STEM careers, (2) what such careers entail, and (3) the connection between STEM projects and their daily life, they are more likely to be interested in STEM.
ROBOTICS AND STEM EDUCATION

The use of robotics is a promising technology for teaching STEM concepts and skills in K-12 education and supports a transdisciplinary approach to STEM education. For example, learning with robotics can provide opportunities for even elementary school students to learn science, programming, and math concepts earlier than expected and “can provide hands-on opportunities for girls at a very young age thus helping to build and develop their confidence and interest in math, science, and engineering” (Rogers & Portsmore, 2004, p. 25). The following sections discuss the significance and use of robotics in K-12 education.

Robotics and Student Learning

Benitti (2012) conducted a meta-analysis of studies investigating the effectiveness of robotics as a teaching tool in K-12 schools. The researcher selected studies where robotics integration occurred in subjects that were not related to the field of robotics such as programming or robot construction. A further criterion used to select studies was the implementation of a quantitative method to evaluate student learning that occurred as a result of the robotics intervention. From a possible 107 studies, Benitti (2012) eventually analyzed 10 studies that met all of the selection criteria. The review findings suggest that generally, the use of educational robotics increases student learning of specific STEM concepts, and in most of these cases, students engaged in self-directed learning experiences that “promoted personalized comprehension of STEM concepts through experimentation” (p. 986).

It should be noted that Benitti (2012) also found that in a few cases, “there [were] studies that have reported situations in which there was no improvement in learning” (p. 978).

For example, in the Nugent, Barker, and Grandgenett (2008) summer camp study, “youth were able to increase test scores across four content areas including mathematics, geospatial concepts (limited but not significant improvement), computer programming, and engineering/robotics” (p. 451). One of the factors cited for the low gains in geospatial concepts was the lack of alignment of the concepts with the traditional middle school science curriculum. Another factor that appeared to affect student learning from robotics interventions was the length of time for the intervention. Students participating in a longer robotics summer program, such as a three-week intervention, demonstrated significantly greater understanding of STEM concepts and showed higher self-efficacy than students participating in a shorter intervention/control
group (Nugent, Barker, Grandgenett, & Adamchuk, 2010). Students exposed to a three-hour robotics intervention in the Nugent et al. (2010) study did not demonstrate increases in their understanding of STEM concepts. However, it was noted that the shorter intervention did have a positive effect on student attitude, with an increase in students’ attitudes and interest towards robotics. The latter results suggest that shorter robotics interventions can play a role in motivating students and increasing interest in STEM subjects and are consistent with the literature that shows that robotics creates a high degree of student interest and engagement in STEM careers (Nugent et al., 2008; Nugent et al., 2010; Robinson, 2005; Rogers & Portsmore, 2004).

While Benitti (2012) reports that the findings from the studies analyzed did not provide conclusive evidence to show that robotics developed specific science process and teamwork skills, a recent study on the use of robotics for teaching in K-12 schools points to the potential for robotics to enhance student understanding of STEM concepts and skills. Ardito, Mosley, and Scollins (2014) studied the use of a robotics program to enhance understanding of math concepts, develop math problem-solving skills, and foster collaboration skills among students in Grade 6. Students were engaged in authentic, inquiry-based robotics challenges where they applied math concepts such as measurement, area, and circumference. Scores on a state standardized math assessment “showed a larger percentage of students with “Above” or “Within” ranges for the Standard Performance Indices in Algebra, Measurement, and Statistics/Probability (all 92%). This level of performance placed them above both their peers within the building and their county” (Ardito et al., p. 85). Students in this study also exhibited growth in their ability to problem-solve and collaborate in groups.

The literature, therefore, suggests that integrating robotics in instruction does support student learning of STEM concepts and skills, but the extent and quality of learning depends on a variety of factors.

**Best Practices for Robotics Integration in Instruction**

While studies in the meta-analysis conducted by Benitti (2012) generally reported gains in student learning of concepts and skills, four studies reported non-significant gains in student learning in some cases. It is, therefore, important to recognize that the mere implementation of robotics does not necessarily promote student learning (Benitti, 2012; Park, 2015). Several factors contribute to successful learning outcomes for students during robotics implementation. These factors include:

- The comfort and skill level of teachers with technology, especially in using the robotics software for programming (Vollstedt, Robinson, & Wang, 2007)
• The attitude of teachers in regards to how they motivate students and promote positive attitudes towards the use of robotics (Lindh & Holgersson, 2007)
• The alignment of the use of the technology tool with educational and student learning goals (Nugent et al., 2008)
• The use of appropriate pedagogical approaches implemented to teach STEM concepts using robotics, such as robotics enhanced inquiry-based learning, also referred to as “REIBL” (Park, 2015) or engineering design (Rogers & Portsmore, 2004)
• Providing multiple entry points into robotics to address diverse student interests and learning styles (Rusk, Resnick, Berg, & Pezalla-Granlund, 2008)
• Providing different activities in robotics programs to differentiate for different levels of content knowledge and problem-solving skills (Williams, Ma, Prejean, Lai, & Ford, 2007)
• Having a large physical space for pupils to engage in experimentation and testing when they conduct robotics activities (Lindh & Holgersson, 2007)
• Creating small student groups (maximum 2-3 pupils per robotics kit) (Lindh & Holgersson, 2007)
• Offering just-in time tutorials, lessons, and debriefings during the problem-solving robotics activities to help students make connections to scientific and engineering concepts (Nugent et al., 2008; Williams et al., 2007)
• Providing technical support for teachers during implementation (Rogers & Portsmore, 2004)

Many of the above factors relate to and depend on the knowledge, skill, and comfort level of the teacher to implement robotics-based activities within classrooms. As such, there is a need to provide teachers with professional learning support that is effective at building both pedagogical knowledge and technical skills for using robotics and other technology to promote student learning of STEM knowledge and skills.

A Professional Learning Model for Technology Integration
Research shows that teacher knowledge about teaching with technology is decontextualized and viewed as remote from practice when the focus of teacher professional learning is on learning technical skills (Angeli & Valanides, 2009; Harris, Mishra, & Koehler, 2007; Harris, Mishra, & Koehler, 2009). When teachers are taught how to teach authentic content with technology (TPACK), this teacher knowledge is
more readily transferrable into classroom practice (Harris & Hofer, 2011; Harris et al., 2007; Harris, et al., 2009; Jaipal-Jamani & Figg, 2015). Figg and Jaipal-Jamani (2013) proposed a model for developing professional learning contexts such as a workshop to promote the shift from a technocentric pedagogy (acquisition of skills approach) to a content-centric pedagogy (develop understandings about teaching content with technology) called the TPACK-based Professional Learning Design Model (TPLDM) (Jaipal-Jamani & Figg, 2015). This professional learning model for technology professional learning consists of four stages: (a) modeling a technology enhanced activity (learning with the tool) to set the context and purpose for tool use; participants experience learning with a specific technology to meet content learning outcomes; (b) engaging in a ‘pedagogical dialogue’ about the modeled lesson; how the tool is used in practice to make connections between the pedagogy, content, and technology; (c) developing activity-specific technical skills through short tool demonstrations, and (d) applying the TPACK knowledge learned to design an activity, using the tool in their own teaching contexts. Such an approach to teacher professional learning provides concrete and relevant experiences that teachers can easily transfer into their teaching practice.

Guidelines for Teacher Professional Learning on Robotics

The TPLDM model that focuses on content-centric pedagogy rather than techno-centric pedagogy offers practical insights to address some of the limitations of using robotics for STEM learning as outlined in the previous section. The following guidelines are suggested for developing teacher knowledge about how to use robotics to enhance student learning of STEM concepts and skills.

- Select expert teacher coaches or train coaches to have expertise in programming skills and in how to effectively use technology to teach STEM content knowledge and skills (TPACK)
- Coaches provide PL to teachers on the basics of programming required for application of the selected robotics technology in STEM areas
- Coaches apply the TPLDM to model an authentic application of the use of robotics using an appropriate pedagogical approach for teaching STEM concepts and skills, and have teachers consider pedagogical implications for practice in different subject areas
- Teachers from different disciplines such as science, math, and technology collaborate in school-based or inter-school STEM teams to develop a transdisciplinary STEM robotics activity or unit to meet student learning goals
- Coaches support teacher teams on-site during planning and implementation, if
required

- Teachers can teach or co-teach units to meet multiple learning goals in multiple disciplines (Jaipal-Jamani & Figg, 2015).

**Recommended Pedagogical Approaches for Robotics Integration**

**Engineering Design Process**

According to Rogers and Portsmore (2004, p. 17) engineering, as building and designing, can motivate, “students to learn math, science, reading, writing, communication, and design skills” through engagement in a project or design process. An engineering approach is interdisciplinary because it requires all of the aforementioned skills to build and design. Rogers and Portsmore outline the design steps that students engage in as follows: “1. identify and formulate a problem, 2. design a solution, 3. create and test a solution, 4. optimize and re-design, and 5. communicate and disseminate the solution” (p. 17).

**Robotics Enhanced Inquiry-based Learning**

The Robotics Enhanced Inquiry-based Learning (REIBL) process is similar to engineering design but the focus is on scientific inquiry processes, supported by robotics. REIBL consists of the five inquiry processes: 1) posing a question (problem); 2) exploring and brainstorming; 3) investigating and designing; 4) testing and documenting results, and 5) sharing results (Park, 2015).

**PROFESSIONAL LEARNING FOR STEM EDUCATION**

The successful implementation of a STEM initiative requires sustained and meaningful support for professional learning to help build capacity for STEM education amongst teachers and administrators. Support that is ongoing and embedded in a teacher’s day-to-day work is shown to be highly effective (Champion, 2003; Guskey, 2002; Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009). Professional Learning Communities (PLCs) represent one model for sustainable professional learning that is gaining widespread popularity and support (Schmoker, 2006; Sparks, 1998; Stoll, Bolam, McMahon, Wallace, & Thomas, 2006). DuFour and Eaker (1998) define PLCs as groups that typically involve collaborative inquiry, share a common vision and core values, are action and results focused, and put student achievement at the centre.

The following examination of STEM PLCs in particular draws largely from two major studies that provide a comprehensive review of the literature that explores the work and traits of STEM PLCs. The first is a 2010 report commissioned by the National
Commission on Teaching and America’s Future (NCTAF) entitled \textit{STEM Teachers in Professional Learning Communities: A Knowledge Synthesis} by Fulton et al. that provides a broad overview and analysis of existing knowledge related to STEM teachers and PLC practice across K-12. The second report by Fulton and Britton (2011), \textit{STEM Teachers in Professional Learning Communities: From Good Teachers to Great Teaching}, is a follow-up to the 2010 study, and provides further synthesis of research and elaboration of findings.

Both studies advocate strongly for PLCs as a form of effective professional learning. As declared at the outset of Fulton and Britton’s (2011) report, “The clear policy and practice implication is that great teaching is a team sport” (p. 4). The PLC structure, as reflected in the research, is a popular mechanism for building strong teaching teams. (Fulton & Britton, 2011). For instance, in their review of over 40 organizations involved in STEM education initiatives, teacher professional learning, or education policy, Fulton et al., (2010) found that every single organization or teacher held positive views towards PLCs, and recommended their use. STEM educators appear to particularly value the opportunity provided in PLCs to work within a collaborative environment and develop a common language that supports the growth of pedagogical content knowledge, focuses on student thinking and achievement, and emphasizes critical evaluation of instructional practice (Shinohara & Daehler, 2008). Stoll et al., (2006) describe the numerous commonalities in processes, impacts, and challenges of PLCs across nations and emphasizes the promise that the PLC model holds for both building professional capacity and for sustainable improvement of educational systems and processes.

While engaging in PLCs is universally recommended, it is important to note here that the body of literature that explores the effects of STEM PLC participation on student achievement is emergent and still quite new (Vescio, Ross & Adams, 2008). The majority of studies focus on math, followed by science, and there is very little at all published on the impacts of PLCs specific to technology education or engineering (Fulton et al., 2010). This limited research base, therefore, is more reflective of practice in math and science than an integrated STEM program.

With this in mind, it is important to highlight the numerous benefits that STEM PLCs can engender. As reported by Fulton and colleagues (2010), teachers stated that participation in PLCs helped them to improve in the following ways:

- Improved understanding of content and pedagogical knowledge and techniques
- Increased feelings of confidence and preparedness to teach STEM subjects
• Enhanced use of more research-based tactics for teaching math and science (e.g., use of inquiry-based learning)

• Enhanced use of more diverse problem-solving strategies to help engage more students (Fulton et al., 2010).

The research also suggests that the PLC model is particularly beneficial for STEM educators teaching diverse student populations (Fulton & Britton, 2011); for enhancing instruction in the area of technology and engineering (Avery & Reeve, 2013), as well as for elementary school teachers who typically do not receive extended undergraduate education in these core domains or adequate professional learning and preparation (Epstein & Miller, 2011).

In addition, online tools are increasingly being used to enhance STEM PLCs and provide new and innovative ways to support group goals and help STEM educators connect (Fulton et al., 2010). While not much literature exists on the effect of online tools to enhance PLC work, some existing studies have found that the active presence of skilled facilitators, the availability of collaboration software (e.g., shared workspaces, interactive whiteboards, messaging features, etc.), and the presence of user-friendly platforms have been identified as important factors for online supports (Fulton & Britton, 2011). Online tools including social media can also enhance face-to-face PLC work by providing a platform for extended, asynchronous discussion or a space to archive and curate relevant information, resources and materials (Fulton et al., 2010).

**CHARACTERISTICS OF EFFECTIVE PLCS**

While PLCs garner high approval ratings from educators in general, the formation of a PLC does not automatically guarantee a fruitful enterprise, as PLCs can sometimes be formed around superficial notions and/or weak forms of implementation, and may, therefore, be less effective or beneficial (Fulton, Doerr & Britton, 2010; Fulton & Britton, 2011). As Saunders, Goldenberg, & Gallimore (2009) argue, “time for collaboration by itself, even when administratively supported, is unlikely to improve achievement unless additional conditions are in place that structure its use” (p. 1028). In their review of existing literature on PLCs, Vescio et al. (2008) found that the only common feature in research that reported gains in student achievement was a “persistent focus” on student learning and achievement (p. 87), as opposed to issues such as teacher relations within the PLC (Goldenberg, 2004), or increasing teacher knowledge without direct application to student learning (Saunders et al., 2009).
In efforts to delineate what makes for effective PLCs for STEM education, Fulton and Britton (2011) identify six major principles that can form the basis of a productive community:

- Shared goal and values
- Collective responsibility
- Authentic assessment
- Self-directed reflection
- Stable settings
- Strong leadership support (p. 5).

In the following section, we elaborate on these principles.

**Shared Goals and Values**
A common vision and shared set of values is identified by many studies as the most important factor for an effective PLC (DuFour, 2004; Fulton & Britton, 2011). Commitment to achieving goals can be nurtured by supporting teacher choice and voice and valuing authentic questions and concerns that arise from practice (Slavit & Nelson, 2009). Moreover, the PLC should be grounded in the ultimate goal of improving student learning as well as the belief that all teachers and students can learn (Raptis & Fleming, 2003).

**Collective Responsibility**
Teachers must acknowledge the connection between their practice and student achievement and understand the work that is involved is dedicated to efforts to improve both (Fulton et al., 2010). The community must share mutual accountability for student achievement, and also be aware and accountable for shared and appropriately differentiated responsibilities (Fulton & Britton, 2011). Community members must be dedicated to “de-privatizing practice” (Newmann & Associates, 1996) and fostering collaboration by sharing both positive and negative classroom experiences, as well as pedagogical knowledge, and student artifacts (Mitchell, 2007).

**Self-directed Reflection**
Reflection and discussion should be oriented around real problems teachers experience in their classrooms and should include concrete tasks that teachers can test out, observe and reflect on with the team (Wilson, 2011). Every member must be committed to participating in a reflective cycle oriented around student achievement which consists of "identifying the current level of student achievement, establishing a goal to
improve the current level, working together to achieve that goal, and providing periodic evidence of progress” (DuFour, 2004, p. 10). The team must co-develop and approve protocols for exploring and evaluating practice, but protocols and practices should themselves be subject to ongoing evaluation to make sure they do not become codified into a technical procedure that is no longer serving the interests of the group (Bybee, 2010).

**Leadership Support**

The presence of a supportive leader in a PLC was found to be imperative to its success. Effective leaders were those who helped to nurture a culture of trust, risk-taking and collaboration, provided supports as well as catalysts for learning, and situated themselves as co-learners in the group (Fulton & Britton, 2011). Leadership support of this kind was found to help deepen discussion, support effective structure, and increase productivity at both the elementary and high school levels (Fulton et al., 2010). The principal’s role can be described as being the “lead teacher,” responsible for creating the conditions for a culture of collaboration within their school and for setting the expectation that participating in the PLC is an essential part of being on staff (Fulton et al., 2010). Principals can also help to sustain gains achieved in PLCs by building and maintaining distributive leadership models that give teachers opportunities to be leaders in the school (e.g., literacy and math coaches) (Fulton & Britton, 2011).

**Authentic Assessment**

Protocols for engaging in analysis and evaluation of student work are important and can help structure a collaborative focus and strategy for the PLC (Fulton et al., 2010). Observing and reflecting on each other’s teaching practices and lessons can also help teachers collaborate on goals and understand what is working, why, and how to go about implementing promising practices in their own classrooms (Fulton & Britton, 2011). However, getting to deep, critical discourse around student data and instructional practice does not necessarily happen automatically. Kennedy, Slavit, and Nelson (2009) warn that PLCs focus on using student data to improve practice rather than “prove” that existing approaches are successful. In a panel discussion documented in the study by Fulton and colleagues (2010), a number of seasoned educators with experience in STEM-focused PLCs observed a trend in the trajectory of group discourse that tended to move from a more surface-level discussion of instructional practice and classroom activities towards a deeper analysis of the connections between these practices and student achievement as the comfort level within a group rose. However, they also felt that PLCs are most productive when dialogue around student learning and evidence of improvement happens as soon as possible. One suggestion to
help stimulate discussion of this type and to build trust and comfort at the beginning stages of a PLC was to have student work from outside the group brought in as artifacts that could be discussed without anyone feeling anxious, threatened or unsure (Fulton et al., 2010).

**Stable Settings**

It is important for STEM teachers to be able to engage in professional development opportunities over extended periods of time (Beatty, 2011; Hanover Research, 2011), as meeting on a regular and sustained basis helps to nurture trust and community norms and protocols (Fulton & Britton, 2011). Continuity matters in a STEM PLC as it helps maintain a common culture and language (Fulton et al., 2010).

All of the previously mentioned principles, shared goals and values, collective responsibility, authentic assessment, self-directed reflection, stable settings, and strong leadership support should work together to foster a culture of trust, risk-taking, and openness within the group. Members need to feel safe engaging in honest reflection, critique, idea-sharing, and discussion with administrators and other teachers - this is especially true when it comes to a STEM-focused enterprise when teachers might be dealing with unfamiliar content and pedagogies (Avery & Reeve, 2013).

**Facilitation**

Not included in the six major principles but an extremely important element to consider for STEM PLC projects is *good facilitation*. The presence of skilled facilitators has been identified as an “essential support” that can enhance a PLC in three main ways: (1) by facilitating knowledge, such as helping to find relevant information and resources if or when it may be needed; (2) by helping to maintain structure and foster positive interaction in the groups; and (3) by keeping the group on target and focused on goals (Fulton & Britton, 2011; Kennedy et al., 2009). While research suggests that it is more difficult for PLCs to work across content areas than it would be for them to be working within one content area alone, a good facilitator can help the group draw out connections across disciplines and encourage exploration and discussion around these points of intersection (Fulton et al., 2010). With respect to online facilitators, research suggests that they play a slightly different role than those mediating face-to-face groups; rather than be positioned as a co-learner, online facilitators are more likely to be regarded as an expert than a peer, are more expected to take on an advisory role and may in fact be the most active participant in the community to ensure that the conversation does not lag, remains focused, and that community members keep connected and make helpful contributions (Fulton et al., 2010). Regardless of platform,
facilitators need to be exposed to ongoing training in facilitation, coaching, and data analysis over an extended period of time to help them shape and hone their skills (Fulton et al., 2010). It is also important to acknowledge that facilitation skills in the classroom not be seen as automatically transferable to facilitation in a professional learning context, whether face-to-face or online. As Fulton and colleagues (2010) insist, “there are many kinds [of facilitation], but all of them require some professional development because facilitating adult learning is different than facilitating student learning” (p. 7).

So, who should facilitate a STEM PLC? What qualifications should they have? There are varied perspectives on this issue. Some argue that a PLC facilitator should not be a peer or colleague, as the inevitability of assuming a leadership role at times could negatively affect the dynamics of the group (Fulton et al., 2010). Another view holds that enabling current teachers to become trained PLC facilitators could provide valuable leadership opportunities (Fulton & Britton, 2011). The notion of coach-as-facilitator in STEM PLCs provides another approach. In what follows, we explore various coaching models, as well as research on the impacts of coaches on teacher beliefs, practice, and student achievement. We conclude this discussion by commenting on the role of a coach in a STEM PLC context.

Coaching for Professional Learning

In their book, The Literacy Coaching Challenge: Models and Methods for Grades K-8, McKenna and Walpole (2008) describe coaching as “a strategy for implementing a professional support system for teachers, a system that includes research or theory, demonstration, practice, and feedback” (p. 1). Coaching as a form of professional learning is considered a high-quality practice that affords the opportunity for sustained, job-embedded learning (Desimone, 2009; Russo, 2004). Numerous studies show that teachers generally enjoy engaging with a coach as a form of professional learning (Armstrong, Cusumano, Todd, & Cohen, 2008; Ferguson, 2011; Diamond & Powell, 2011). While research on the effect of coaching to improve classroom practice and student achievement is limited (Cornett & Knight, 2008), the experimental studies that do exist are “overwhelmingly positive” (see Blazar & Kraft, 2014, pp. 542-566. for more detailed discussion of this literature). Cornett and Knight (2008) present a summary of the beneficial impacts that various forms of coaching were found to have on teacher attitudes, practice, efficacy, and student achievement. They concluded that coaching:

- Increases teachers’ job satisfaction
- Increases the likelihood of implementation/ skill transfer, and can help greatly
raise implementation rates if used as ongoing follow-up support to one-time events such as workshops

- Positively impacts teachers’ sense of self-efficacy

With regard to observable impacts on student achievement, most of the evaluative literature in this area has examined the efficacy of literacy-oriented programs such as Reading First (Blazar & Kraft, 2014; Cornett & Knight, 2008). However, there are some studies that highlight benefits for other content areas as well as non-content specific practice (Blazar & Kraft, 2014). For example, a study by Campbell and Malkus (2011) found that a two-year coaching program in math that focused on knowledge, pedagogy, and curriculum had a significantly positive impact on student achievement. Related research shows gains from web-based coaching focused on student-teacher interaction in both teacher behavior (Gregory, Allen, Mikami, Hafen, & Pianta, 2014) and student success (Allen, Pianta, Gregory, Mikami, & Lun, 2011). It remains inconclusive whether online coaching programs are more, less or equally effective than those conducted face-to-face (Blazar & Kraft, 2014). Other research, including both theoretical and empirical studies, suggests that teacher coaching is an effective practice for professional learning that can have a positive impact on teacher attitudes, practice, and efficacy, as well as student achievement (Allen et al., 2011; Campbell & Malkus, 2011; Cornett & Knight, 2008; Desimone, 2009; Neuman & Cunningham, 2009; Russo, 2004; Sailors & Price, 2010).

While research demonstrating the benefits of coaching is growing, other studies have shown less positive results. For example, Marsh, McCombs, & Martorell (2012) found that less than half of teachers receiving coaching support (47% for reading and 40% for social studies) claimed that their coach influenced their instructional practice to any great extent, with almost one quarter to one third of teachers in the respective domains reporting no influence at all (Marsh et al., 2012). Other studies show little to no difference between teacher groups who received coaching on specific aspects of their professional learning program and those who did not (Carlisle & Berebitsky, 2010; Whitaker, Kinzie, Kraft-Sayre, Mashburn, & Pianta, 2007). Sailors et al. (2014) reported on a five-month coaching program and found that teachers’ beliefs were changed as a result of participating in a coaching program, however, the average level of implementation was not very high. While some coaching experiences can positively impact teacher beliefs and preconceptions, they can also present an obstacle to change. For example, a 1989 study by Tobin and Espinit explored the impact of two coaching models designed to improve teaching and learning in science - one where a university science educator was a coach and the other a high school science teacher. They found
no improvement in instruction and identified the teachers’ prior beliefs about teaching and learning, coupled with a low level of content knowledge, as the strongest barriers to change in teaching practice (Tobin & Espinit, 1989). Finally, researchers have also observed negative effects on the teacher-coach relationship when the coach held a prior supervisory role with their matched teacher (Dechenne et al., 2012).

The literature also suggests that certain coaching practices and program features can make a notable difference in terms of impact. For instance, research shows that the more mismatched the teacher perceives the coach to be in terms of grade level and (especially) content, the less helpful the teacher reported the coach to be (Dechenne et al., 2012). Research has also shown a possible threshold effect where coaches who work with more than 12 teachers are less effective than those who work with a fewer number (Atteberry & Bryk, 2011). Time-density is another critical factor. Ramey and colleagues (2011) conducted a comparative study that followed teachers randomly assigned to two variations of a coaching program - both included the same number of total hours but one was a high intensity five-week program and the other was spread out over 20 weeks. The researchers found that the participants in the high-intensity program showed greater gains than those in the program with more dispersed hours. Similarly, Ross (1992) conducted a study of Ontario coaches and concluded that the more time coaches spent with teachers, the more classroom gains were found. Related studies support these claims (Garet, Porter, Desimone, Birman, & Yoon, 2001; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007).

In addition to these factors, leadership support for coaching was found to be one of the most powerful elements for success. Sumner (2011) identified frequent principal and coach meetings as a practice that had a measurable impact on program success: “Key to the success of the principal and coach relationship is utilizing the coach as a teacher leader, as a support for the principal’s role as instructional leader, and as a resource for the principal as well as teachers” (p. 113). Other research underscores this observation. Walpole, McKenna, Uribe-Zarain, and Lamitina (2010) studied the relationship between coaching and classroom instruction in 116 low SES schools and found that the schools that demonstrated the strongest gains were those that also exhibited strong leadership support for their coaches. Alternatively, a lack of principal support was found to be a common obstacle to coaching (Richard, 2003).
Steckel (2009) argues that administrators need to help create a school culture that values inquiry and professional learning in order for coaches to be impactful. Similarly, in a discussion focusing on the administrator’s role in supporting coaching programs, Heineke and Polnick (2013) stress the importance of the principal’s role in helping to set the needed conditions in their school before a coaching program even begins: “the principal is key in helping the instructional coach get a foot in the door by establishing a climate for professional growth and expectations for success in classrooms that embrace change” (p. 48). Toward this end, Heineke and Polnick (2013) outline five key recommendations to administrators that can help lay the foundation for a successful coaching program:

1. Clearly define the coach’s role.
2. Publicize the coach’s role widely so that it does not become confused with other duties.
3. Safeguard the coach’s duties. As Heineke and Polnick (2013) assert “the coach should never be viewed as a staff evaluator” but as being “in the trenches” with the teachers (p. 50).
4. Facilitate collaboration and create space in or directly after the school day for coaches and teachers to meet together.
5. Hire trained coaches that have access to ongoing support and learning themselves.

These kinds of research advances illuminate important aspects of coaching as a form of professional learning, and also help point the way towards promising directions for future research. Certainly, there is much more to be learned about what makes for an effective coaching program (Cornett & Knight, 2008). While the research base in this area is new, studies that explore the characteristics of successful STEM coaching are even more important. Our research on the first year implementation of the TDSB STEM strategy can make a significant contribution to address this gap in the literature.

**Coaching Models**

There is a multiplicity of forms that coaching can take when put into practice (Cornett & Knight, 2008). McKenna and Walpole (2008) describe three different coaching approaches that are particularly relevant to the needs of STEM PLCs, including peer coaching, subject-specific coaching, and reform-oriented coaching. Following are brief descriptions based on their research, supplemented with findings from supporting studies.
**Peer Coaching**
This form of coaching has been formally recognized as a professional learning model for over 30 years (Joyce & Showers, 1982). It is typically aimed at addressing a targeted problem, and generally involves teachers within a single school coaching one another, although an outside expert can also be called in for professional learning. This approach helps build relationships among staff, is inexpensive, and is beneficial for advancing a single, school-wide strategy. However, the approach relies heavily on a single strategy and there can often be few quality controls to ensure standards and quality of professional learning. Nevertheless, studies that explore this form of coaching have found it to dramatically improve knowledge transfer and implementation of skills in teaching practice (Baker, 1983; Bush, 1984; Joyce & Showers, 1982; Showers, 1982; Showers, 1984).

**Subject Specific/Instructional Coaching**
This coaching model targets a single subject area as well as subject-specific standards. There is no established approach for implementation, and it is generally not evaluative. Coaches help ensure effective implementation of practice, encourage teachers, promote reflection, and monitor student outcomes (Koh & Neuman, 2006). Instructional coaching is considered a powerful practice because it enables accessible, sustained, job-embedded support at a school-wide level (Brady, 2007; Knight, 2005; Knight, 2009; Poglinco & Bach, 2004).

**Reform-Oriented Coaching**
This approach to coaching is adaptive to local contexts and will look different in different places; goals are also flexible and can change over time. However, this model is the most intrusive of all the approaches and so it may be met with some teacher resistance. In this system, coaches are either “directors” or “mentors”, and typically bear a lot of responsibilities, including the following: helping teachers identify problems to be addressed, dealing with implementation issues, aiding with assessment and evaluation, monitoring progress, charting growth over time; interpreting and displaying data; and designing and implementing a reflexive professional support system (McKenna & Walpole, 2008).

These approaches do not necessarily have to be mutually exclusive, but can be blended to create hybrid models that provide flexible and evolving solutions to meet particular needs (McKenna & Walpole, 2008).
Sailors and Price (2015) advocate for a blended model referred to as the “Support for the Improvement of Practices through Intensive Coaching or “SIPIC” approach” (Sailors & Shanklin, 2010). This model was developed to improve literacy coaching in particular, and was created as an attempt to synthesize aspects of “directive” or intentional coaching with “responsive” or needs-based coaching to leverage the best elements of both. The SIPIC model centres on a few key features: it is embedded within the day-to-day life of a school; it features qualified coaches that are specially trained in reading instruction; it relies on frequent interaction between coaches and teachers; and coaches work in the classrooms with teachers and students on an ongoing basis. Research has shown this model to be viable for helping literacy teachers improve their instructional practice (Sailors & Price, 2015).

Knight (2007) offers another model that focuses on instructional or subject-specific coaching in particular. According to this framework which Knight calls a “partnership approach,” there are seven foundational principles: equality, choice, voice, dialogue, reflection, praxis, and reciprocity. This framework is grounded in varied disciplines, including psychology, cultural anthropology, business, adult education, and draws together ideas from prominent educational thinkers such as Paolo Freire (1970), Peter Senge (1990), William Isaacs (1999), and others. Knight (2007) found that teachers who participated in this coaching approach followed through with implementation and newly learned strategies more frequently than those who did not, with application rates at about 85%.

In a review of the literature exploring best practices for instructional coaches, Sumner (2011) highlights five areas that have been found to have positive impacts on classroom outcomes:

- Help teachers with lesson analysis
- Help teachers interpret and apply assessment data
- Assist with lesson planning
- Observe and discuss practices with teachers
- Model lessons

A coaching model that can work for STEM professional learning needs to be multifaceted, and include supports for both content and non-content specific practice, as well as assessment and evaluation, equity, application of technology, and so on. A focus on transdisciplinarity such as that emphasized in the TDSB STEM strategy also needs to
enable professional learning around classroom-based innovation and new pedagogies that are at the cutting edge of the field. It is important to note here that while coaches often take on many different roles in a school (Lynch & Ferguson, 2010; Mraz, Algozzine, & Watson, 2008; Walpole & Blamey, 2008), shouldering too many responsibilities can decrease a coach’s effectiveness (Smith, 2007). While this observation remains speculative, it is plausible to think that embedding a coach within the supportive structure of a STEM PLC can provide an approach for enhancing the learning community and leveraging the coach’s role within a school without overburdening the coach. Indeed, coaches have been recognized as a valuable addition to PLCs by helping to spur critical thinking, support risk-taking and idea generation, and focus data-driven discussions (Barkley, 2015; Heineke & Polnick, 2013). Moreover, conversations that occur in PLCs can help the coach identify points of focus for closer observations or can be the space where observations are explored as a group (Barkley, 2015).

Moreover, many of the recognized practices and conditions for effective coaching programs align with those of successful PLCs. For instance, establishing a foundation of trust and respect is paramount in both contexts (DuFour, DuFour & Eaker, 2008; Sumner, 2011), as is focusing on increasing student achievement through critical reflection of practice and use of assessment data (Sumner, 2011). Additionally, the ongoing and embedded learning that both models can accommodate allows for coaches to gain knowledge of students, which numerous studies have shown to be an important factor for coaching success (Johnson & Donaldson, 2007; Steiner & Kowal, 2007).

Models for STEM Professional Learning at the TDSB
As part of the TDSB’s Vision and Action plan to support student achievement and well-being, STEM programming was to be implemented across the Board.⁵ From this perspective, a reform-oriented approach as described by McKenna and Walpole (2008) is relevant. The flexibility and transformational goals inherent in this approach are in line with the endeavour to create a robust and effective transdisciplinary STEM program. However, the role of “coach-as-director” is incongruous with the vision to cultivate collaborative, inquiry-based teaching teams and is not reflective of the coaching qualities and practices that are supported by the TDSB, as outlined in this same document. For example, the Orientation Package for TDSB STEM Learning Coaches recommends that coaches “avoid going in [to a school] as an “expert”… honour the site teachers’ knowledge & expertise. Model collaboration and facilitate learning. Engage in

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⁵ For details on the system vision and action plans as of May 4, 2016, please see the details in: http://www.tdsb.on.ca/AboutUs/DirectorofEducation/YearsofAction.aspx
co-planning rather than a complete takeover of the site teacher’s responsibilities” (TDSB 2014c, p. 29).

Moreover, while the current model has one coach assigned to eight schools, mechanisms for extending peer-to-peer learning beyond the time that the specialized STEM coach is available, such as developing school-based STEM PLCs, would be beneficial. Integrating other supports for effective peer coaching might also be considered. Additionally, given the particular needs of STEM PLCs to deepen understanding within, across, and even beyond disciplinary boundaries, finding and highlighting effective ways to integrate subject-specific and instructional coaching within a STEM-focused PLC could help nurture positive relationships among members and create an atmosphere where distributed leadership is both activated and valued. Coaches could help teachers draw connections between disciplinary concepts and rise above disciplinary frameworks.

For example, Roehrig et al. (2012) investigated what models of STEM integration were used by secondary school science, math, and technology teachers to integrate STEM in their instruction. An overview of the year-long professional development process, which included 10 teacher PLC teams being supported to develop STEM activities or units, is described in detail by Roehrig et al. (2012). Consistent with a reform-oriented approach, teacher PLCs had flexibility in choosing the approaches they preferred to plan and implement STEM activities. Four structural approaches to planning for STEM integration emerged: (1) co-teaching (multiple teachers in the same classroom co-developed and co-taught the unit (e.g., a science and mathematics teacher in an engineering class); (2) team teaching, multiple teachers instructing within a unit but teaching students in their own disciplines (e.g., a science teacher introduced the problem context and a math teacher used the context and data to teach math principles to that same group of students); (3) team planning with individual implementation (a group of teachers plan together and implement the same experience in their individual classrooms); and (4) individual planning and implementation. Roehrig et al. (2012) concluded that their study findings suggest that “STEM integration can be implemented most successfully when mathematics and science teachers work together both in a single classroom (co-teaching) and in multiple classrooms (content teaching- common theme)” (p.31). They emphasize further that, “Science and mathematics teachers, if provided with appropriate professional development, have the capacity to integrate engineering and content in meaningful ways for their students” (p. 43). It may be worthwhile to explore how coaches can support PLC teacher teams engaged in co-teaching and team teaching across disciplines to promote a transdisciplinary approach to STEM integration.
SECTION III: STUDY ON YEAR ONE IMPLEMENTATION OF THE TDSB’S K-12 STEM STRATEGY

Introduction
The purpose of this study was to examine the first year implementation of the TDSB STEM K-12 strategy and track preliminary outcomes for teachers and students engaged in this strategy. Data will continue to be collected by the Research Department to track the TDSB STEM strategy over a three-year period. This document reports the results from year one of three.

The study included 60 pilot STEM lead schools as part of the TDSB’s system-wide STEM strategy. School administrators, teachers, students, and STEM Learning Coaches all participated in this study. Survey data were collected from participating school administrators, teachers, STEM Learning Coaches and students from Grades 3-8 and Grades 9-12. Responses were compared and contrasted by evaluating survey responses to questions on STEM teaching and learning practices, perceptions of STEM education, STEM professional learning activities, and perceptions of the TDSB STEM strategy implementation. In conducting the study, data were collected using a variety of sources and methods including: Likert rating scales, open-ended survey questions, and closed survey questions.

Methodology and Study Participants
In total, 60 pilot STEM lead schools took part in the study of the first year implementation of the TDSB STEM strategy during the 2014-15 school year. These schools were selected by the STEM program implementation team at the central office. The participant pool in this study was made up of STEM Learning Coaches, school administrators, teachers, and students from these STEM lead schools. In total, 10 STEM Learning Coaches, 50 school administrators, 80 teachers, and 439 students from Grades 3-8 and Grades 9-12 participated in this study.

Data Collection Procedures and Study Surveys
The study analyzed responses to survey questions on STEM teaching and learning practices, perceptions of STEM education, STEM professional learning activities, and feedback on the TDSB STEM strategy implementation. Researchers compared answers from STEM Learning Coaches, administrators, teachers, and students by evaluating survey responses and classifying themes related to the TDSB STEM strategy implementation.
All participants were invited to complete an electronic survey. Participants were sent the survey electronically, given as much time as needed, were told that the goals of the survey was to learn more about the perceptions and practices of STEM education, and were assured that their identity and responses would be kept strictly confidential. A paper version of the survey was also available at the request of participants.

Teachers were told that the results of the survey were to be used for effective Board Improvement Planning towards the TDSB’s Years of Action 2013-2017, and the goal of the survey was to collect their perceptions and practices of STEM education and identify the effectiveness of professional learning activities. Teachers were told the survey would take approximately 25 minutes of their time.

Administrators were also asked to complete a survey on the TDSB’s K-12 STEM strategy. Administrators were given the same pre-survey explanation as teachers in that they were told that the goal of the survey was to collect their perceptions and practices related to STEM education and identify the effectiveness of professional learning activities. Like teachers, administrators were informed that the results of the survey were to be used for effective Board Improvement Planning towards TDSB’s Years of Action 2013-2017. The administrators were told that the survey would take approximately 20 minutes of their time.

STEM Learning Coaches were asked to complete an electronic survey on the TDSB’s K-12 STEM strategy. Similar to administrators and teachers, STEM Learning Coaches were told that the goal of the survey was to collect their perceptions and practices related to STEM education and to identify the effectiveness of professional learning activities. STEM Learning Coaches were also told the results of the survey were to be used for effective Board Improvement Planning towards TDSB’s Years of Action 2013-2017. It was estimated that the survey would take 15 minutes.

Students whose schools participated in the TDSB’s K-12 STEM strategy were asked to complete an electronic survey on the TDSB’s K-12 STEM strategy. The students were given class time to complete the surveys. Younger students (Grades 3-8) were provided guidance, if needed, from their teacher in completing the survey.

Students in Grades 3-12 were told that the survey was about Science, Technology, Engineering and Math, a project of the TDSB. In the list of instructions to complete the survey, students were asked to take time to think about their answer and think about what was true for themselves. They were also told that the survey was not a test and
that there were no right or wrong answers. Finally, they were told that the results were confidential and even their teacher would not see the results.

In order for students to take part in the survey, an information letter and form was sent home to parents about the survey. Parents were told that if they did not wish their child to participate in the survey, they could indicate their selection on the form and return it to the child’s teacher.

The surveys were created by the TDSB Research Department based on the work of various authors and researchers who work in areas related to the field of STEM education and/or 21st century learning. The questions on the student survey were based on the work of the Friday Institute for Educational Innovation (2012a, 2012b, 2012c), Ravitz (2014), Coffman (2012), and the ASTEE (n.d.) questionnaire primary level.

Following are detailed charts indicating the survey constructs for each survey question in the teacher, administrator, STEM Learning Coach, elementary school student and secondary school student surveys.

Table 1 depicts the Teacher Survey items and their associated constructs used in the survey that was administered during the 2014-15 school year.

<table>
<thead>
<tr>
<th>Table 1: Teacher Survey Items, Constructs and Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questions on Survey</td>
</tr>
<tr>
<td><strong>STEM EDUCATION ATTITUDES, PERCEPTIONS &amp; KNOWLEDGE</strong></td>
</tr>
<tr>
<td>PART A: 1-3</td>
</tr>
<tr>
<td>PART C: 11</td>
</tr>
<tr>
<td>PART A: 4</td>
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<tr>
<td>PART A: 4</td>
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<tr>
<td>PART A: 6</td>
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<tr>
<td>PART C: 9</td>
</tr>
<tr>
<td><strong>STEM PROGRAMMING AND IMPLEMENTATION</strong></td>
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<tr>
<td>PART B: 1-2</td>
</tr>
<tr>
<td>PART C: 6</td>
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<tr>
<td>PART C: 7</td>
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<tr>
<td>PART C: 10a&amp;b</td>
</tr>
<tr>
<td>PART E: 11</td>
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</tbody>
</table>
Table 2 depicts the Administrator Survey items and their associated constructs used in the survey that was administered during the 2014-15 school year.

Table 2: Administrator Survey Items, Constructs and Sources

<table>
<thead>
<tr>
<th>Questions on Survey</th>
<th>Items #</th>
<th>Constructs</th>
<th>Source</th>
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<tr>
<td><strong>STEM EDUCATION ATTITUDES, PERCEPTIONS &amp; KNOWLEDGE</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>PART A: 1-3</td>
<td>12</td>
<td>Perceptions of STEM (e.g., knowledge of STEM integration; Perceptions of STEM to improve student learning; Viability and relevance of STEM as a pedagogical approach)</td>
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<td>PART C: 11</td>
<td>1</td>
<td>Wish to see STEM implementation continued at school</td>
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<td><strong>STEM IMPLEMENTATION</strong></td>
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<td>PART B: 1</td>
<td>1</td>
<td>Stage of STEM implementation</td>
<td>Gjøvik (2013) modified</td>
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<td>PART B: 2</td>
<td>12</td>
<td>Process and strategies to implement STEM programming</td>
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<td>PART B: 7</td>
<td>1</td>
<td>Challenges schools experienced in implementing STEM</td>
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<td>PART B: 8</td>
<td>5</td>
<td>Barriers to implementation of TDSB STEM strategy</td>
<td>Gjøvik (2013)</td>
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<td>PART C: 10</td>
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<td>Types of school leadership needed for successful implementation of TDSB STEM strategy</td>
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<td>PART C: 12a&amp;b</td>
<td>2</td>
<td>Feedback on STEM Learning Coach model</td>
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<tr>
<td>PART C: 13</td>
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<td>Recommendations for implementing the TDSB STEM strategy</td>
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Table 3 depicts the STEM Learning Coach survey items and their associated constructs used in the survey that was administered during the 2014-15 school year.

Table 3: STEM Learning Coach Survey Items, Constructs and Sources

<table>
<thead>
<tr>
<th>Questions on Survey</th>
<th>Items</th>
<th>Constructs</th>
<th>Source</th>
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<td>1</td>
<td>Attendance in professional learning session</td>
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<td>Coaches’ knowledge and skills to support pilot STEM lead schools</td>
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<td>PART A: 3</td>
<td>1</td>
<td>Overall quality of orientation</td>
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<td>PART A: 4</td>
<td>1</td>
<td>Suggestions to improve orientation</td>
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<td><strong>PROFESSIONAL LEARNING AND SUPPORT</strong></td>
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<td>PART A: 5-6</td>
<td>27</td>
<td>Professional learning and support provided</td>
<td>TDSB (2014b); TDSB Research Department</td>
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<td><strong>STEM PROGRAM IMPLEMENTATION</strong></td>
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<td>PART A: 7</td>
<td>1</td>
<td>Challenges schools experienced in implementing STEM</td>
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<td>PART B: 1-2</td>
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<td>Barriers to STEM implementation</td>
<td>Gjøvik (2013); TDSB Research Department</td>
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<td>Types of school leadership needed for successful implementation of TDSB initiative</td>
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<td>Recommendations for implementing the TDSB STEM strategy</td>
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<td><strong>ADDITIONAL QUESTIONS</strong></td>
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<td>Additional comments</td>
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<td><strong>BACKGROUND CHARACTERISTICS</strong></td>
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<tr>
<td>PART C: 1-3</td>
<td>3</td>
<td>Demographics</td>
<td>TDSB Research Department</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
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</table>
Table 4 depicts the Elementary School Student survey items and their associated constructs used in the survey that was administered during the 2014-15 school year.

Table 4: Elementary School Student Survey Items, Constructs and Sources

<table>
<thead>
<tr>
<th>Questions on Survey</th>
<th>Items #</th>
<th>Constructs</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>PART A: 1</td>
<td>2</td>
<td>Teacher practices: Problem-based learning</td>
<td>Coffman (2012)</td>
</tr>
<tr>
<td>PART A: 1</td>
<td>4</td>
<td>Teacher practices: Collaboration</td>
<td>Ravitz (2014); TDSB Research Department</td>
</tr>
<tr>
<td>PART A: 1</td>
<td>2</td>
<td>Teacher practices: Creativity</td>
<td>Coffman (2012); ASTEE (n.d.) primary level</td>
</tr>
<tr>
<td>PART A: 1</td>
<td>2</td>
<td>Teacher practices: Using technology</td>
<td>Coffman (2012)</td>
</tr>
<tr>
<td>PART A: 1</td>
<td>3</td>
<td>Teacher practices: Global learning</td>
<td>TDSB Research Department</td>
</tr>
<tr>
<td>PART A: 2</td>
<td>11</td>
<td>21st century learning skills</td>
<td>Friday Institute for Educational Innovation (2012a)</td>
</tr>
<tr>
<td>PART A: 3</td>
<td>4</td>
<td>Self-efficacy (Inquiry-based learning)</td>
<td>Coffman (2012)</td>
</tr>
<tr>
<td>PART A: 3</td>
<td>3</td>
<td>Self-efficacy (Creativity)</td>
<td>ASTEE (n.d.) primary level</td>
</tr>
<tr>
<td>PART A: 3</td>
<td>2</td>
<td>Self-efficacy (Collaboration)</td>
<td>Ravitz (2014); TDSB Research Department</td>
</tr>
<tr>
<td>PART A: 4</td>
<td>2</td>
<td>Feedback about STEM class</td>
<td>TDSB Research Department</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
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Table 5 depicts the Secondary School Student survey items and their associated constructs used in the survey that was administered during the 2014-15 school year.

Table 5: Secondary School Student Survey Items, Constructs and Sources

<table>
<thead>
<tr>
<th>Questions on Survey</th>
<th>Items #</th>
<th>Constructs</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>PART A: 1</td>
<td>2</td>
<td>Teacher practices: Problem-based learning</td>
<td>Coffman (2012)</td>
</tr>
<tr>
<td>PART A: 1</td>
<td>4</td>
<td>Teacher practices: Collaboration</td>
<td>Ravitz (2014); TDSB Research Department</td>
</tr>
<tr>
<td>PART A: 1</td>
<td>2</td>
<td>Teacher practices: Creativity</td>
<td>Coffman (2012); ASTEE (n.d.) primary level</td>
</tr>
<tr>
<td>PART A: 1</td>
<td>2</td>
<td>Teacher practices: Using technology</td>
<td>Coffman (2012)</td>
</tr>
<tr>
<td>PART A: 1</td>
<td>3</td>
<td>Teacher practices: Global learning</td>
<td>TDSB Research Department</td>
</tr>
<tr>
<td>PART A: 2</td>
<td>11</td>
<td>21st century learning skills</td>
<td>Friday Institute for Educational Innovation (2012b)</td>
</tr>
<tr>
<td>PART A: 3</td>
<td>5</td>
<td>Self-efficacy (Inquiry-based learning)</td>
<td>Coffman (2012)</td>
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</table>
### ABOUT YOU AND SCHOOL

<table>
<thead>
<tr>
<th>Questions on Survey</th>
<th>Items #</th>
<th>Constructs</th>
<th>Source</th>
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</thead>
<tbody>
<tr>
<td>PART A: 3</td>
<td>3</td>
<td>Self-efficacy (Creativity)</td>
<td>ASTEE (n.d.) secondary level</td>
</tr>
<tr>
<td>PART A: 3</td>
<td>3</td>
<td>Self-efficacy (Collaboration)</td>
<td>Coffman (2012), Ravitz (2014)</td>
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<td>PART A: 4</td>
<td>1</td>
<td>Relevance of STEM</td>
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<tr>
<td>PART A: 4</td>
<td>1</td>
<td>Students’ sense of belonging</td>
<td>TDSB Research Department</td>
</tr>
<tr>
<td>PART A: 4</td>
<td>2</td>
<td>Mechanisms in our schools to support students with career choices, post-secondary education choices, course selection, deciding on future goals</td>
<td>TDSB Research Department</td>
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<td>PART A: 5</td>
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<td>Feedback about STEM class</td>
<td>TDSB Research Department</td>
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<tr>
<td>PART A: 5</td>
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<td>Feedback about STEM class</td>
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<td>PART B: 1</td>
<td>12</td>
<td>Interest in STEM careers</td>
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<tr>
<td>PART C: 1-2</td>
<td>2</td>
<td>Demographics</td>
<td>TDSB Research Department</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Background Characteristics

| TOTAL               |         |             |        |

**Safeguards on Confidentiality**

The identity of each survey participant was kept strictly confidential. Permission was obtained from participants before participation began. The study applied processes of Research Ethics from the Toronto District School Board.

**Limitations of this Study**

This research was intended to provide data to inform planning and decision-making to the TDSB regarding the implementation of the TDSB’s K-12 STEM strategy. This is the first year of three for the study. According to Fullan (2001), school and district improvement in large-scale initiatives need more than one year to see considerable effects on student learning and well-being outcomes. The timeline for requiring evidence on student learning by mid-June limits the empirical data and information that is available through research (i.e., EQAO, report cards, course pass rates, graduations, post-secondary pathways, absenteeism, etc.). However, baseline data have been established and will be tracked over time to examine the effects of the TDSB STEM strategy on student learning and achievement and teacher practice, as well as on board improvement.

**Data Analysis Strategy**

The data in this study are intended to answer the following research questions:

1. Did the STEM Learning Coaches receive the training needed to support the pilot STEM lead schools?

2. Do the pilot STEM lead schools have the resources, professional learning, and support they need to deliver STEM programming?
3. What are teachers’ and administrators’ perceptions of STEM education? How do they perceive the viability and relevance of STEM education?

4. What are teachers’ knowledge of STEM careers, STEM pedagogy, and STEM resources?

5. What is teachers’ sense of self-efficacy regarding STEM education? What practices do teachers use to teach STEM?

6. What STEM skills and competencies have students developed through their involvement in the STEM program? What are students’ interests in STEM careers?

7. What stage have the pilot schools reached in their implementation of the TDSB STEM strategy?

8. What can we learn from the first year implementation of the TDSB STEM strategy, including the factors that hinder its implementation? What are the recommendations for moving forward with the implementation of the strategy?

Research question one examined the professional learning support that STEM Learning Coaches received. STEM Learning Coaches’ responses to survey questions about the STEM Learning Coach orientation and professional learning support provided were examined and analyzed for common themes, recommendations and/or issues.

For research question two on whether the pilot schools have the resources, professional learning and support they need to deliver STEM programming, administrator, teacher and STEM Learning Coach survey results were examined and compared for themes. Important findings related to the amount of support the pilot schools received were identified. Administrators were asked about the STEM resources and professional learning support received, organizational support, and school needs. While teachers were asked about the professional learning and support received, professional learning and support needs and organizational support, STEM Learning Coaches were only asked about the professional learning and support provided.

For research question three on teachers’ and administrators’ perceptions of STEM education, results from the teacher and administrator survey questions on their perceptions of STEM education were analyzed and examined for key findings. Teachers and administrators were asked 12 questions related to their perceptions of STEM education.
For research question four on teachers’ knowledge of STEM careers, STEM pedagogy and STEM resources, results from the teacher survey were examined and analyzed. Teachers were asked questions on STEM competencies, pedagogy, resources, and knowledge of careers.

For research question five on teachers’ sense of self-efficacy, educator and student survey results were analyzed for themes relating to self-efficacy. Teachers were asked questions related to their self-efficacy in STEM subject content and teaching. Elementary and secondary school students were asked self-efficacy questions related to inquiry-based learning, creativity, and collaboration.

For research question six, which examined STEM skills and competencies students have developed through the TDSB STEM strategy, student and educator surveys were analyzed. Student responses to questions on 21st century learning, global learning, students’ sense of belonging, relevance of STEM, and interest in STEM careers were analyzed. Teachers’ responses to questions on the development of their students’ STEM skills such as self-direction, collaboration, and creativity were also examined.

For research question seven, addressing the stage of implementation reached by the pilot schools in the TDSB STEM strategy, administrator survey results, educator survey results, and STEM Learning Coach survey results were analyzed. Administrators were asked about what stage of implementation the school had reached, barriers, challenges, and recommendations for the future. Teachers were asked about STEM programming and implementation challenges, barriers, and feedback and recommendations. STEM Learning Coaches were also asked STEM programming and implementation challenges, barriers, types of school leadership needed, and feedback and recommendations. These results were compared, contrasted and analyzed.

For research question eight, focusing on what we can learn from the first year of implementation, administrator, educator, STEM Learning Coach, and student survey responses were analyzed and examined to address the key findings from this study.

In order to identify the areas and statements in which students and teachers differed in their responses, statistically significant tests were conducted and examined for each of the items on the surveys. Asterisk (*) symbols were used in the charts to identify if there was a significant difference at the 0.05 level.
Table 6 summarizes the key research questions and data collection methods used in the study.

<table>
<thead>
<tr>
<th>Key Research Questions</th>
<th>Data Collection Methods</th>
</tr>
</thead>
</table>
| 1. Did the STEM Learning Coaches receive the training needed to support the pilot STEM lead schools? | • STEM Learning Coaches survey (Year One)  
• Interviews with STEM Learning Coaches (Year 2) |
| 2. Do the pilot STEM lead schools have the resources, professional learning and support they need to deliver STEM programming? | • Educator, Administrator and STEM Learning Coaches surveys (Year One)  
• Interviews with Central leadership team, STEM Learning Coaches, school administrators and teachers (Year Two) |
| 3. What are teachers’ and administrators’ perceptions of STEM education? How do they perceive the viability and relevance of STEM education? | • Educator, Administrator and STEM Learning Coaches surveys (Year One) |
| 4. What are teachers’ knowledge of STEM careers, STEM pedagogy, and STEM resources? | • Educator survey (Year One) |
| 5. What is teachers’ sense of self-efficacy regarding STEM education? What practices do teachers use to teach STEM? | • Educator and Student survey (Year One) |
| 6. What STEM skills and competencies have students developed through their involvement in the STEM program? What are students’ interests in STEM careers? | • Educator and Student surveys (Year One)  
• Classroom observation (Year Two)  
• Interviews with STEM Learning Coaches, school administrators, and teachers (Year Two) |
| 7. What stage have the pilot schools reached in their implementation of the TDSB STEM strategy? | • Administrator survey (Year One) |
| 8. What can we learn from the first year implementation of the TDSB STEM strategy, including the factors that hinder its implementation? What are the recommendations for moving forward with the implementation of the strategy? | • Administrator, Educator, STEM Learning Coaches, and Student surveys (Year One)  
• Interviews with Central leadership team, STEM Learning Coaches, school administrators and teachers (Year Two) |

**Longitudinal Mixed-Method Research Framework**

Three years longitudinal mixed-method research design, using both qualitative and quantitative data gathering and analyses, was employed to examine the STEM implementation in the TDSB. This will allow us to monitor and evaluate the effectiveness of the educational program, quality of professional learning, leadership, educational technology integration and impacts on student and teacher learning and engagement, as well impacts on school and board improvement overall.

**Figure 9: The Stokes Research Matrix**

Teachers using technology to support 21st century teaching and learning and STEM education are the key mediators for the sustainable implementation of the 21st century Innovation Research Initiative focusing on the TDSB’s K-12 STEM Strategy. “As the application of technology is aligned with provincial curriculum standards, teachers are required to incorporate it into their daily schedule to support the design of successful collaborative, customized, self-directed and active learning environments” (ISTE, 2008, as cited in Sinay, 2014, p.27)\(^6\).

This research lies in Pasteur’s Quadrant of the Stokes Research Matrix (Stokes, 1997) targeted to understand the current STEM teaching and learning practices across the board but at the same time considering to use the research findings for improvement and generalization for public education as a whole (see Figure 9).

We are applying longitudinal mixed-method pre- and post-test equivalent groups’ research design. The first year of the study involved creating a strong theoretical foundation that showed effects on leadership, teachers’ practice, attitudes, and beliefs as well as student learning outcomes. The second year intends to go deeper and focus on teacher engagement, leadership, professional learning, teachers’ TPACK knowledge and teaching practices, and technology integration (using the Substitution Augmentation Modification Redefinition (SAMR) model\(^7\)). As a result of these focuses on technology and teacher pedagogy, year two will examine their effects on students’ higher order cognitive skills (Bloom’s Digital Taxonomies), global competencies, engagement, well-being and overall achievement\(^8\).

Baseline student, teacher, and administrator data have been established from those who directly engaged in the TLF Innovation Strategy (i.e., STEM pedagogy) for the last two years. Student achievement and engagement will be studied through standardized assessments (e.g., EQAO), teacher grades (e.g., report cards), course marks, credit accumulation, post-secondary pathways, absenteeism, and caring and safe schools data using multi-level Hierarchical Linear Modelling (HLM), taking into account net student outcomes within the context of their learning within and across schools. We have

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\(^7\) For further details on SAMR model, please visit: [http://hippasus.com/blog/](http://hippasus.com/blog/)

\(^8\) This is based on feedback provided on “information request for technology learning fund planning” based on email communication from Frank Kelly on May 2 and Gerry Connelly on May 11, 2016.
adopted a peer review approach, as surveys were based on the work of experts in the field of STEM education and 21st century learning.

This comprehensive research methodology allows us to not only measure the growth in student achievement but also identify the correlational and causational factors affecting student achievement such as teacher engagement, technology integration, leadership, teachers’ previous experience and engagement in professional learning and many more areas that are outlined more specifically in research question five. Figure 10 visually shows our research framework in relation to the TDSB’s K-12 STEM strategy implementation.

This current report covers the first stage of our research framework. Some of the areas of research inquiry and reporting will be:

- Teaching and Learning with Robotics: Effectiveness of Professional Learning and Impacts on Teacher Practice and Student Learning, Achievement, Engagement and Belonging (research tools used: pre- and post- TPACK survey with teacher and student surveys and interviews, and classroom observations in relation to standardized assessment outcomes and system data on report cards, course pass rates, credit accumulations, post-secondary pathways, absenteeism, suspensions and expulsions).

- Teaching and Learning with Coding: Effectiveness of Professional Learning on Teacher Practice and Student Learning (research tools used: pre- and post- TPACK with coding surveys with system data on student achievement, engagement and well-being).

- Digital Lead Learners (DLLs) as Agents of Scaling up Technology Integration and Innovation in the TDSB (research tools used: pre- and post- STEM DLL surveys and post- overall DLL and STEM-DLL surveys, and surveys on TPACK and technology integration).

- Coherence and System Wide Educational Program Implementation (research tools used: STEM leadership and administrator interviews based on the Public Education Leadership Project (PELP) Coherence model).


This is based on feedback provided on “information request for technology learning fund planning” based on email communication from Frank Kelly on May 2, 2016 and Gerry Connelly on May 11, 2016.
• Differential Effects of Teacher Engagement, Leadership, and Technology Integration on Student Learning (research tools used: teacher engagement, leadership and technology integration surveys and interviews in STEM elementary schools in relation to standardized assessments outcomes and system data on report cards, course pass rates, credit accumulations, post-secondary pathways, absenteeism, suspensions and expulsions).

• Learnings from Year II STEM Education in the TDSB (research tools used: STEM teacher surveys, teacher and administrator interviews and classroom observations in elementary pilot STEM lead schools).

• STEM or STEAM Education (based on interviews and survey findings specifically on this question triangulated with empirical research findings).

• Coaching and Recommendations for Effective System-wide Program Implementation (research tools used: interview findings on leadership teams and coaches as well as the survey findings).

11 For further information on PELP model please visit: http://pelp.fas.harvard.edu/book/coherence-framework.
Laying the Theoretical and Practical Foundations for STEM Education in TDSB through Collaborative Leadership and Empirical Research

**Figure 10: Heuristic Research Framework in Relation to the TDSB’s K-12 STEM Strategy Program Implementation**

**Key Research Questions**

- **Phase I**
  - STEM Theoretical Foundation
  - STEM education attributes
  - High-Quality professional learning
  - Review of STEM implementation & teaching and learning practices
  - Educators’ & students’ attitudes, beliefs, opinions, knowledge, practices and self-efficacy
  - Teachers’ and students’ development of STEM skills and practices

- **Phase II**
  - Going Deeper
  - Research Evidence Informing Second Year Implementation
  - Change in Teacher practice and Engagement
    - Focus on Teaching and learning with Robotics and Coding
    - Improvement in Student Engagement, belonging, global competencies and academic outcomes
  - TDSB K-12 STEM Strategy Process Map
  - System-wide feedback loop and modification
    - 2014-2015
    - 2015-2016
    - 2016-2017

- **Phase III**
  - Scaling Up
  - Research Evidence Informing Third Year Implementation
  - Revising STEM goals and action plans
  - Deeper teaching and learning with technology
  - STEM Pedagogy focusing on early years, global competencies, numeracy, equity and inclusive learning
  - Longitudinal mixed method, pre- and post- randomized control group research designs with peer review opportunities
  - Quantitative & Qualitative Data Gathering: Surveys, classroom observations, interviews, classroom visits, document analyses
  - Data Analyses & formation of interrelated themes
  - Rearrangement of themes & comparison of emergent theory with existing theory

**Phase I: STEM Learning Coaches**

- We begin by investing in STEM instructional leadership.
- We sent trained STEM Learning Coaches to work in schools with administrators and teachers to improve STEM knowledge, engagement, understanding and interest in STEM.

**Phase II: Educators**

- We further laid the foundation for STEM by improving teacher knowledge, engagement and classroom practices with STEM.
- Teachers were provided with ongoing professional development on STEM including: STEM Learning Coaches, workshops, and professional development sessions, on topics ranging from implementation, curriculum, lesson planning and teaching strategies.

**Phase III: STEM LEARNING COACHES**

- Our next foundational step is building school leadership support for STEM education.
- School leadership support is a necessary condition for providing STEM education for all with a culture of adaptability, openness and resilience among our school administrators, teachers and students will feel supported with STEM.

**Students**

- Our ultimate goal is to provide STEM education for all. Our objective is to provide students with opportunities to apply their knowledge and skills within the context of real world problems, and finally improving student knowledge and achievement.
SECTION IV: FINDINGS OF THE STUDY

Summary of Results
This study is intended to answer the following questions. Each study question allowed us to learn more about the first year implementation of the TDSB STEM strategy, including factors that hinder its implementation. Following is a brief summary of the results of each research question, and a summary conclusion of what we can learn.

1. Did the STEM Learning Coaches receive the training needed to support the pilot STEM lead schools?

2. Do the pilot STEM lead schools have the resources, professional learning, and support they need to deliver STEM programming?

3. What are the teachers’ and administrators’ perceptions of STEM education? How do they perceive the viability and relevance of STEM education?

4. What are teachers’ knowledge of STEM careers, STEM pedagogy, and STEM resources?

5. What is teachers’ sense of self-efficacy regarding STEM education? What practices do teachers use to teach STEM?

6. What STEM skills and competencies have students developed through their involvement in the STEM program? What are the students’ interests in STEM careers?

7. What stage have the pilot schools reached in their implementation of the TDSB STEM strategy?

8. What can we learn from the first year implementation of the TDSB STEM strategy, including the factors that hinder its implementation? What are the recommendations for moving forward with the implementation of the strategy?

1. Did the STEM Learning Coaches receive the training needed to support the pilot STEM lead schools?

STEM Learning Coaches felt that they received somewhat good training needed to support the pilot STEM lead schools. They felt that the training provided to them gave them a greater understanding of STEM education and made them more aware of the various technologies available for STEM education; however, they would like to receive more ongoing training as STEM Learning Coaches. STEM Learning Coaches would like time to gain new knowledge from each other. They would also like to have their training
focused on: (1) dealing with educator pushback, (2) having more direction on how to coach, and (3) assessment and evaluation strategies for STEM teaching and learning.

2. Do the pilot STEM lead schools have the resources, professional learning, and support they need to deliver STEM programming?

The results of the study show that the STEM pilot schools received some of the necessary resources, professional learning, and support they needed to deliver impactful STEM programming, but that there was still more that could be done.

Pilot school administrators reported that while they received STEM resource kits, other resources including STEM monographs and interactive probeware and software technologies were not as widely received. Only 22% of schools received STEM monographs and 28% received interactive probeware and software technologies.

Administrators and teachers reported that STEM Learning Coaches provided excellent support in the following ways: (1) providing STEM teaching and learning resources, (2) supporting teachers in using the STEM resource kits and monographs, (3) providing professional learning focused on hands-on learning experiences, and (4) co-planning with teachers and assisting with classroom lessons and programs.

Administrators and teachers felt that STEM Learning Coaches provided effective professional learning opportunities, however, they both felt that there were some areas that could be improved upon such as: (1) providing career information, (2) assisting with STEM start-ups, and (3) developing assessment criteria for STEM teaching and learning. Both teachers and administrators felt that the school nurtures a culture of trust and risk-taking, but both perceived that teachers in the school did not really work as an innovative team. Administrators felt that the school did not provide enough time for teachers to plan and implement STEM teaching activities.

Teachers and administrators would like to see the following professional learning activities to support the implementation of STEM education: (1) continued and consistent access to STEM Learning Coaches, (2) more time for planning and collaboration, (3) more resources (i.e., unit plans, technology, activities), (4) best practices/teaching strategies for STEM education, (5) more professional learning, (6) time to observe others teaching, and (7) more partnerships, school-to-school, and between schools and outside organizations.
3. **What are teachers’ and administrators’ perceptions of STEM education? How do they perceive the viability and relevance of STEM education?**

Teachers and administrators were asked about their perceptions of STEM education. Overwhelmingly, teachers and administrators would like the STEM implementation to be continued. Ninety-eight percent (98%) of administrators and 82% of teachers said they would like to see the STEM implementation continued.

Teachers and administrators felt strongly about the importance of STEM education to improve student learning. Teachers and administrators believed that STEM education can help prepare students with the skills and competencies they need. They also agreed that it helped to enhance student learning, solve real-world problems, and engage students in inquiry or problem-based learning. On the other hand, some administrators and teachers felt that the STEM transdisciplinary approach can diminish the individual importance of each content area. In addition to that, some teachers had the perception that STEM education was a “fad”; however, administrators believed that STEM was an educational initiative here to stay.

4. **What are teachers’ knowledge of STEM careers, STEM pedagogy, and STEM resources?**

Teachers were asked about their knowledge of STEM careers, pedagogy, and resources. In terms of STEM careers, many teachers felt that they did not have a developed knowledge of STEM careers. Thirty-seven percent (37%) of teachers said they did not know where to go to learn more about STEM careers, and 23% of teachers felt that they did not have a strong knowledge of current STEM careers.

In comparison, teachers said that they had the necessary knowledge and understanding of STEM pedagogy and available resources. Teachers said that they had an understanding of the following areas of STEM pedagogy: inquiry-based learning, problem-based learning, and how to use various STEM related technology, and understanding the importance of integrating different content areas when teaching. However, one area of STEM pedagogy in which teachers felt that they could improve was the engineering design process. Many teachers said that they did not have a full understanding of this process.

In terms of STEM resources, most teachers (90%) were aware of the use of various technologies for STEM education, but many teachers (58%) had not used the STEM education resources on the TDSB’s STEM K-12 Academic Workspace (AW) Site.
5. **What is the teachers’ sense of self-efficacy regarding STEM education? What practices do teachers use to teach STEM?**

Overall, teachers are confident in their ability to teach STEM effectively. Teachers feel that they are continually improving their STEM teaching practice; however, some teachers (40%) question whether they have the necessary skills to teach STEM.

The most common practices teachers use to teach STEM are: (1) using technology to share information, (2) having students take an initiative when confronted with a difficult question, and (3) using technology to support team work and collaboration.

The least used practices to teach STEM are: (1) having students choose their own topics of learning or questions to pursue, (2) discussing issues related to global interdependency, and (3) creating joint projects using contributions from each student.

Most teachers feel that they have tried to develop students’ STEM skills, but some teachers said that they find it difficult to effectively assess STEM skills. Teachers report that they regularly use a variety of teaching practices that support creativity and innovation such as having students generate their own ideas to a problem and invent a solution to a complex question. However, not all practices are used to the same extent and teachers rarely have students create an original product or performance to express their ideas.

The majority of teachers regularly use teaching practices that foster collaboration skills. Just over two thirds of teachers reported that they have students work with others to set goals and have students collaborate to create joint products all the time or often. Global connections are not being fostered to the same degree as the other teaching practices/student skills. Thirty-one percent of teachers report that they never or rarely discuss issues related to global interdependency.

6. **What STEM skills and competencies have students developed through their involvement in the STEM program? What are students’ interests’ in STEM careers?**

Elementary and secondary school students were asked about the STEM skills and competencies they had developed in the STEM program. Both elementary and secondary school students believed that STEM education engaged them and helped them learn new information. They also felt strongly that the STEM skill they had developed the most was respect, and the area in which they needed more development was time management. Elementary school students felt that STEM classes gave them
the opportunity to build things, use technology and work in groups. In comparison, secondary school students said that STEM education was relevant and meaningful to their life or future career. Overall, the results demonstrate that students’ STEM skills and competencies could be better fostered and improved in the following areas: (1) connecting with students in different parts of the world, (2) using technology to share information with others, and (3) improving students’ time management skills.

The results demonstrate that students are very interested in STEM careers. In fact, the most popular career interests among secondary school students included: (1) careers that allow them to create or design things, (2) technology, and (3) science.

Students felt that more could be done in the school to support them with their career choice. They also reported that teachers and guidance counsellors could have more discussions with them about potential career options and preparing for post-secondary education.

7. **What stage have the pilot schools reached in their implementation of the TDSB STEM strategy?**

At the time of the survey, most of the pilot schools (76%) were at the Partial Implementation stage. The Partial Implementation stage refers to the fact that STEM methodology is being implemented in training, but not all teachers are implementing it yet (Gjøvik, 2013). The remaining schools were at the Full Implementation stage (16%) or Preparation stage (8%).

Most of the schools have implemented the following activities and processes to implement the TDSB STEM strategy: (1) use of a STEM Learning Coach, (2) professional learning, (3) interdepartmental learning and teaching, and, (4) upgrades to technology.

Administrators and teachers were asked about the challenges they experienced in implementing STEM. The challenges included:

- Not having enough time allocated (i.e., release time for planning)
- Not having enough classroom time
- Not having enough time with STEM Learning Coaches
- Lack of resources (e.g., more financial support was needed to buy resources and purchase supplies)
• Not having enough professional learning (e.g., more STEM Learning Coaches needed, PL sessions)
• Lack of teacher confidence/understanding of STEM teaching and learning
• Resistance to change
• Unclear directions on how to cover the curriculum and include STEM-related activities

Teachers and administrators were asked about barriers to STEM implementation. Administrators felt that the largest problem was a lack of needed resources, followed by a lack of teacher content knowledge of STEM. Teachers, on the other hand, felt that the largest problem was a limited availability of professional learning opportunities.

Most administrators and teachers felt that the STEM Learning Coach model was an effective approach for professional learning. Eighty percent (80%) of administrators and 73% of teachers reported they felt the STEM Learning Coach model was a very effective or moderately effective model. On the other hand, 20% of administrators and 26% of teachers reported that they felt the STEM Learning Coach model was not at all effective or slightly effective.

Teachers and administrators who felt that the STEM Learning Coach model was slightly effective or not at all effective were asked for their input on coaching. They made the following suggestions:

• Hire more STEM Learning Coaches
• STEM Learning Coaches need to be on-site more consistently and more often
• STEM Learning Coaches should be part of the school staff
• More experienced STEM Learning Coaches with greater depth of knowledge should be selected
• Have the principal be the STEM Learning Coach

Administrators were asked about the types of leadership the principal should provide to enable the successful implementation of the TDSB STEM strategy. The top responses included:

• Provide support (e.g., provide access to resources, provide time for planning innovative programming)
• Be a leader (e.g., forward thinking, growth mindset, encouraging, etc.)
• Be a risk-taker (e.g., openness to change, thinking outside the box, willingness to think about alternatives)
• Provide professional learning (e.g., STEM Learning Coaches, collaboration among departments)

Teachers and administrators were also asked to share their recommendations for moving forward with the implementation of the TDSB STEM strategy. Both teachers and administrators believed that there needed to be additional funding for more resources, such as more coaches, lessons plans, and new technology and classroom laptops. Another important recommendation made by both teachers and administrators was to allow more time for the TDSB STEM strategy to develop and give it continued support.

**RESULTS: STEM LEARNING COACHES**

*Did the STEM Learning Coaches receive the training needed to support the pilot STEM lead schools?*

The TDSB’s STEM Learning Coaches were asked a series of questions about the training and support they received in their role as coaches. The goal of the survey was to identify coaches’ perceptions and practices related to STEM education and their perception of the effectiveness of the professional learning activities provided to them.

**OVERALL SUMMARY:** STEM Learning Coaches felt they received somewhat good training needed to support the pilot STEM lead schools. They felt the training provided gave them a greater understanding of STEM and made them more aware of the various technologies available for STEM education. However, STEM Learning Coaches would like to have more ongoing training for coaches focused on: (1) dealing with educator pushback, (2) having more direction on how to coach, and (3) assessment and evaluation strategies for STEM teaching and learning.

Overall, the STEM Learning Coaches felt that the program was very successful, but perceived that the program could use some small changes such as more professional learning time for coaches.

**Overall Study Demographics**

Ten TDSB STEM Learning Coaches took part in the study. Each coach completed a survey to gather their perceptions and practices of STEM education and the professional learning activities provided to them. The STEM Learning Coaches in this study worked with a variety of schools representing all grade levels.
Summary: The study included 10 STEM Learning Coaches who worked at all grade levels. The regular role of these coaches included working as elementary and secondary school teachers whose area of concentration included: Mathematics, Science, Technology and Special Education.

Focus of Work of STEM Coaches
STEM Learning Coaches were asked about the focus of their work. Individual STEM Learning Coaches focused on certain grade levels; nonetheless, all grade levels were equally represented among all the coaches. Fifty percent (50%) of the STEM Learning Coaches focused on K-6, 50% of coaches focused on Grades 7 and 8, and 50% of coaches focused on secondary school (see Figure 11).

Figure 11: Focus of Work of STEM Coach

<table>
<thead>
<tr>
<th>What is the focus of your work as a STEM Learning Coach and/or STEM Instructional Leader in 2014-15? (Check all that apply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-6</td>
</tr>
<tr>
<td>Grades 7 and 8</td>
</tr>
<tr>
<td>Secondary</td>
</tr>
</tbody>
</table>

Note: Percentages do not add up to 100% as respondents were able to select more than one response.

Regular Role within TDSB
STEM Learning Coaches were asked about their regular role within the Board when not working as a STEM Learning Coach. The regular role of the coaches included working as elementary and secondary school teachers. Forty percent (40%) of the STEM Learning Coaches worked as elementary school teachers, while 50% worked as secondary school teachers. There was one individual who may have worked in a different role as they selected the option of “Other” (see Figure 12).

Figure 12: Regular Role with the TDSB

Coach: Regular Role within the Board
- Secondary Teacher 50%
- Elementary Teacher 40%
- Other 10%
Concentration Area in Which You Teach

If you are a teacher, in which concentration area do/did you teach? (Check all that apply)

<table>
<thead>
<tr>
<th>Concentration Area</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom Teacher</td>
<td>60%</td>
</tr>
<tr>
<td>The Arts</td>
<td>30%</td>
</tr>
<tr>
<td>Business Studies</td>
<td>10%</td>
</tr>
<tr>
<td>Foreign Languages</td>
<td>n/a</td>
</tr>
<tr>
<td>Gifted/Enrichment</td>
<td>30%</td>
</tr>
<tr>
<td>Guidance</td>
<td>n/a</td>
</tr>
<tr>
<td>Language Arts</td>
<td>40%</td>
</tr>
<tr>
<td>Library or Media Services</td>
<td>n/a</td>
</tr>
<tr>
<td>Mathematics</td>
<td>80%</td>
</tr>
<tr>
<td>Music</td>
<td>20%</td>
</tr>
<tr>
<td>Physical Education/Health</td>
<td>20%</td>
</tr>
<tr>
<td>Science</td>
<td>80%</td>
</tr>
<tr>
<td>Social Sciences</td>
<td>40%</td>
</tr>
<tr>
<td>Special Education</td>
<td>50%</td>
</tr>
<tr>
<td>Technology</td>
<td>50%</td>
</tr>
<tr>
<td>None of the above</td>
<td>n/a</td>
</tr>
<tr>
<td>Other</td>
<td>10%</td>
</tr>
</tbody>
</table>

Note: Percentages do not add up to 100% as respondents were able to select more than one response.

The STEM Learning Coaches in this study taught in a wide range of subject areas, including mathematics, science, technology, special education, social science, and the arts. The most common areas of concentration included: mathematics (80%), science (80%), technology (50%), and special education (50%) (see Figure 13).

Did the STEM Learning Coaches receive the training needed to support the pilot STEM lead schools?

STEM Learning Coaches Orientation

In September 2014, there was a STEM Learning Coach orientation and professional learning opportunity for all of the STEM Learning Coaches involved in the TDSB STEM strategy. All of the STEM Learning Coaches in this study attended the orientation.

Coaches’ Knowledge and Skills to Support Pilot STEM Lead Schools

The STEM Learning Coaches were asked 10 statements about their perceptions of the STEM Learning Coach orientation they attended. Their overall perception of the orientation revealed important findings about the quality of the orientation. Coaches felt that the orientation gave them a greater understanding of STEM education and made them more aware of the various technologies available for STEM education. The two statements with the highest overall mean scores were: “I have a greater understanding of STEM” and “I am aware of the use of various technologies for STEM education” with a mean of 5.11 out of 6 for both of these statements. There were some areas for improvement with regards to the orientation, including having more time for
sharing of STEM resources, learning more about assessment and evaluation strategies for STEM teaching and learning, and learning how to support teachers to use inquiry-based learning in the classroom. These three statements had the lowest mean scores with 4.22, 4.44 and 4.44, respectively.

In all of the 10 statements, the lowest rating among the coaches was “somewhat disagree.” There were no selections of “strongly disagree” or “disagree” for any of the 10 statements. Overall, the coaches were somewhat pleased with the STEM Learning Coach orientation with an overall mean rating of 4.66 out of 6 (see Figure 14).

**Summary:** Overall, the coaches were somewhat pleased with the STEM Learning Coach orientation with an overall mean of 4.66 out of 6. Coaches felt that the orientation gave them a greater understanding of STEM education and made them more aware of the various technologies available for STEM education. Coaches did express that there were some areas for improvement with regards to the orientation, including having more time for sharing of STEM resources, learning more about assessment and evaluation strategies for STEM teaching and learning, and learning how to support teachers to use inquiry-based learning in the classroom.

**Figure 14: STEM Learning Coaches Orientation**
( coaches’ Knowledge and Skills to Support Pilot STEM Lead Schools)

<table>
<thead>
<tr>
<th>Please rate how much you agree or disagree with the following statements about the STEM Learning Coach Orientation.</th>
<th>Strongly Disagree(1)/ Disagree(2)/ Somewhat Disagree(3)</th>
<th>Strongly Agree(4)/ Agree(5)/ Somewhat Agree(6)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) I have a greater understanding of STEM.</td>
<td>0%</td>
<td>100%</td>
<td>5.11</td>
</tr>
<tr>
<td>b) I have an understanding of Inquiry-based learning and how to support teachers to use this strategy to develop the various STEM competencies.</td>
<td>0%</td>
<td>100%</td>
<td>4.44</td>
</tr>
<tr>
<td>c) I have an understanding of Problem-based learning and how to support teachers to use this strategy to help students develop the various STEM competencies.</td>
<td>0%</td>
<td>100%</td>
<td>4.67</td>
</tr>
<tr>
<td>d) I have an understanding of the Engineering design process and how to support teachers to use this strategy to help students develop the various STEM competencies.</td>
<td>0%</td>
<td>100%</td>
<td>4.89</td>
</tr>
<tr>
<td>e) I have shared STEM education resources on the TDSB STEM K-12 Academic Workspace (AW) site.</td>
<td>22%</td>
<td>78%</td>
<td>4.22</td>
</tr>
<tr>
<td>f) I am aware of the use of various technologies for STEM education.</td>
<td>0%</td>
<td>100%</td>
<td>5.11</td>
</tr>
<tr>
<td>g) I have an understanding of the problems/inquiries/lessons linked to the STEM resource kits.</td>
<td>11%</td>
<td>89%</td>
<td>4.56</td>
</tr>
<tr>
<td>h) I have an understanding of the STEM Monographs and how they are used to make connections within various disciplines.</td>
<td>0%</td>
<td>100%</td>
<td>4.56</td>
</tr>
<tr>
<td>i) I have an understanding of assessment and evaluation strategies (e.g., assessment of process).</td>
<td>33%</td>
<td>67%</td>
<td>4.44</td>
</tr>
<tr>
<td>j) I am well-prepared for my role in supporting the schools assigned to me.</td>
<td>11%</td>
<td>89%</td>
<td>4.56</td>
</tr>
<tr>
<td>Overall</td>
<td>8%</td>
<td>92%</td>
<td>4.66</td>
</tr>
</tbody>
</table>

**Overall Quality of STEM Learning Coaches Orientation**

STEM Learning Coaches perceived that the overall quality of the orientation was good, but had room for improvement. There was a wide range of perceptions of the overall quality of the orientation with rankings from “excellent” to “poor.” Forty-four percent
(44%) of coaches ranked the orientation as “good,” whereas only one person ranked it as “excellent,” two people ranked it as “very good,” one ranked it as “fair”, and one ranked it as “poor” (see Figure 15).

**Summary:** STEM Learning Coaches perceived that the overall quality of the orientation was good, but had room for improvement. There was a wide range of perceptions of the overall quality of the orientation with rankings ranging from “excellent” to “poor.”

**Suggestions to Improve the STEM Learning Coaches Orientation**

STEM Learning Coaches were asked for their suggestions to enhance the orientation session. The main suggestions provided were to have: (1) more direction on how to coach and (2) more professional development on how to deal with teacher pushback.

**Summary:** The suggestions of the STEM Learning Coaches for ways to improve the orientation include having: (1) more direction on how to coach and (2) more professional development on how to deal with teacher pushback.

**Professional Learning and Support**

STEM Learning Coaches were also asked about the professional learning and support they provided to the pilot STEM lead schools. Overall, the STEM Learning Coaches provided comprehensive professional learning and support services in a variety of capacities at the schools (see Figure 16). These services included professional learning focused on hands-on learning experiences, supporting teachers in the use of various teaching strategies, providing STEM teaching and learning resources, and participating in or running STEM showcases. The coaches worked with the STEM Implementation Professional Learning team, specific departments within the school, as well as with individual teachers (see Figure 16).
The STEM Learning Coaches provided a variety of supports to their designated schools. These included the following areas of support: (1) setting STEM programming goals, (2) developing success criteria for the STEM program, (3) providing professional learning focused on a variety of hands-on learning, (4) supporting teachers in using various teaching strategies, (5) providing STEM teaching and learning resources, (6) supporting teachers’ use of STEM resource kits, (7) co-planning lessons and programs, (8) assisting with professional development on various technologies, (9) providing career information, (10) assisting with STEM start-ups, (11) participating in or running STEM showcases, and (12) providing assessment and evaluation strategies. The results showed that 100% of the coaches provided support in 9 out of the 12 areas. The three areas that did not receive support from all of the coaches were: (1) developing success criteria and metrics to assess the effectiveness of the STEM program (90% support), (2) providing career information (70% support), and (3) assisting with STEM start-ups (80% support) (see Figure 17). These three areas could be given more attention in the future.

Coaches were asked to rate the level of support they provided in each support area. The coaches provided the most support in the following areas: (1) providing professional learning focused on a variety of hands-on learning experiences, (2) co-planning with teachers on classroom lessons and programs, (3) providing STEM teaching and learning resources, and (4) assisting with professional development for teachers on various technologies. On the other hand, the areas receiving the least support were as follows: (1) developing success criteria and metrics to assess the effectiveness of the STEM program, (2) providing career information, and (3) providing assessment and evaluation strategies.
Figure 17: Professional Learning and Support

<table>
<thead>
<tr>
<th>Professional Learning (Type of support support provided)</th>
<th>a) Support Provided</th>
<th>b) Extent of Support Provided</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>Not Really/Minor Extent</td>
</tr>
<tr>
<td>Setting goals to move along the STEM continuum</td>
<td>100%</td>
<td>10%</td>
</tr>
<tr>
<td>Developing success criteria and metrics to assess the effectiveness of the STEM program</td>
<td>90%</td>
<td>78%</td>
</tr>
<tr>
<td>Providing professional learning focused on a variety of hands-on learning experiences</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Supporting teachers in how to use various strategies - Inquiry-based learning, Problem-based learning, and the Engineering design process - to help students develop STEM competencies</td>
<td>100%</td>
<td>10%</td>
</tr>
<tr>
<td>Providing STEM teaching and learning resources</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Supporting teachers in using the STEM resource kits and monographs</td>
<td>100%</td>
<td>40%</td>
</tr>
<tr>
<td>Co-planning with teachers and assisting them with classroom lessons and programs</td>
<td>100%</td>
<td>20%</td>
</tr>
<tr>
<td>Assisting with professional development for teachers on various technologies</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Providing career information</td>
<td>70%</td>
<td>86%</td>
</tr>
<tr>
<td>Assisting with STEM start-ups (e.g., clubs)</td>
<td>80%</td>
<td>25%</td>
</tr>
<tr>
<td>Participating in or running the STEM showcases</td>
<td>100%</td>
<td>20%</td>
</tr>
<tr>
<td>Providing assessment/evaluation strategies (e.g., assessment of process)</td>
<td>100%</td>
<td>60%</td>
</tr>
</tbody>
</table>

Summary: STEM Learning Coaches indicated that they provided comprehensive professional learning and support services in a variety of capacities. The coaches regularly worked with the STEM Implementation Professional Learning Team (PLT), specific departments within the school, as well as individual teachers. The results show that 100% of the coaches provided support in 9 out of the 12 support areas. The three areas where some coaches provided the least support were in regards to: (1) developing success criteria for STEM (90% support), (2) providing career information (70% support), and (3) assisting with STEM start-ups (80% support). The coaches provided the most support in the following areas: (1) providing professional learning focused on a variety of hands-on learning experiences, (2) co-planning with teachers on classroom lessons and programs, and (3) assisting with professional development for teachers on various technologies. The areas that received the least support were as follows: (1) developing success criteria and metrics to assess the effectiveness of the STEM program, (2) providing career information, and (3) providing assessment and evaluation strategies for STEM teaching and learning.

STEM Program Implementation

Challenges Schools Experienced in Implementing the TDSB STEM Strategy

STEM Learning Coaches were asked to comment on the greatest challenges their designated schools have experienced in implementing the TDSB STEM strategy. According to coaches, the greatest challenges included: (1) the perception of staff that the TDSB STEM strategy was just another board initiative, (2) a lack of school resources, and (3) not having enough ongoing administrative support.
In terms of the issue of staff seeing the TDSB STEM strategy as just another board initiative, many of the school staff felt there were already too many initiatives in the school and they did not see a priority for the TDSB STEM strategy. To add to that, one of the challenges faced by coaches was not having enough ongoing support from administrators. This is an important issue, as teacher and administrator support are key in order for an initiative to be integrated, developed and supported. At the beginning of the TDSB STEM strategy, coaches felt they had administrator support but as the initiative progressed, the support was not always there.

In regards to the issue of a lack of school resources, coaches reported that some schools have failing or old technology, lack of structured release time for teachers, and not enough “ready-made” STEM lessons.

**Summary:** According to STEM Learning Coaches, the greatest challenges that STEM schools experienced in implementing STEM strategy included: (1) the perception of staff that the STEM strategy was just another board initiative, (2) a lack of school resources (old technology, release time, money for PD, not enough “ready-made” lessons, and (3) not having enough ongoing administrative support.

**Barriers to the TDSB STEM Strategy Implementation**

STEM Learning Coaches were asked to rate a series of statements relating to the barriers to the TDSB STEM strategy implementation. By far, the biggest barrier identified was the perception of teachers or administrators that STEM was another “fad” that would soon go away. This statement had the highest overall mean rating among the coaches, with a mean of 5.20 out 6. Other barriers to implementation mentioned by coaches included: (1) the culture of the school, (2) lack of leadership and support from the school principal, and (3) limited availability of professional learning opportunities. All three of these statements had a mean of 4.70 out 6.

Interestingly, coaches did not perceive teacher content knowledge, a lack of trained teachers, and negative perceptions of inquiry-based learning to be barriers to the TDSB STEM strategy implementation. In fact, these statements received the lowest overall mean ratings among the coaches, with a mean of 3.90 out of 6.

Coaches were also asked to identify other factors that have hindered the implementation of the TDSB STEM strategy. Their main comments included: (1) not having enough time to spend in each school, (2) the school having too many initiatives and the lack of priority on STEM, (3) the lack of structured release time for teachers to
work with the coach, and (4) not having enough teacher buy-in/support from administration.

Summary: STEM Learning Coaches were asked to comment on the barriers to the STEM implementation. By far, the biggest barrier that they identified was that STEM was perceived by teachers or administrators as another “fad” that would soon go away. Other barriers included: (1) the culture of the school, (2) lack of leadership and support from the school principal, and (3) limited availability of professional learning opportunities. Other factors noted include: (1) not having enough time to spend in each school, (2) the school having too many initiatives, and the low priority on STEM, (3) lack of structured release time for teachers to work with the coach, and (4) not having enough teacher buy-in/support from administration.

Types of School Leadership Needed for Successful Implementation of the TDSB Strategy

Coaches were asked to provide their input on the types of school leadership needed to enable the successful implementation of the TDSB STEM strategy. The main message from coaches was that there needs to be a clear and consistent message of what STEM is and what STEM Learning Coaches do. Having a consistent message of the TDSB STEM strategy is a fundamental condition for success as it lays the foundation of the program.

The following recommendations were also made by coaches: (1) ensuring a strong relationship and understanding between the coach and administrator to determine what the school needs and what its direction is in relation to STEM programming, (2) having regular recognition and celebration of success with staff, (3) having leadership support of structural changes (e.g., timetabling, room allocation) and, (4) allowing for mentorship that is meaningful and not superficial.

Summary: STEM Learning Coaches were asked for their input on the types of school leadership needed for successful implementation of the TDSB STEM strategy. The recommendations included:

- A consistent message to all administrators/Superintendents about what STEM is and what STEM Learning Coaches do.
- A strong relationship and understanding between the coach and administrators of what the school needs and what its direction is in relation to STEM programming.
- Regular recognition and celebration of success with the staff.
- Leadership support of structural changes (e.g., timetabling, room allocation)
- Mentorship that is meaningful and not superficial
Feedback on Coaching Model

STEM Learning Coaches were asked for their feedback on which type of coaching model they thought was most effective and why. They were asked to choose between STEM Learning Coaches, Hybrid Teacher Coaches, or other. Overwhelmingly, the coaches felt the best model was to have STEM Learning Coaches who are teachers working in central office. Ninety percent (90%) of coaches chose this option (see Figure 18).

From the perspective of coaches, the STEM Learning Coach model was perceived to be most effective because it enabled STEM Learning Coaches to focus their efforts entirely on moving the TDSB STEM strategy forward. This model allowed for undivided attention to this strategy as compared to the Hybrid Teacher Coach model, where the staff worked as a teacher for half of the day and coach for the other half of the day. The coaches also explained that it would be challenging for hybrid teachers to divide their time well between their classroom and teaching responsibilities and their coaching. Added to that, there was no guarantee that a Hybrid Teacher Coach would use extra timetable periods for STEM teaching.

One coach suggested an alternative model that would include 10 coaches and 20 hybrid coaches as a way to combine both the STEM Learning Coach model and the Hybrid model.

Figure 18: Feedback on Coaching Model
Recommendations for Implementing the TDSB STEM Strategy

STEM Learning Coaches were asked about recommendations for moving forward with the implementation of the TDSB STEM strategy. The main recommendations focused on professional development for coaches and creating more structure to the STEM program. First, STEM Learning Coaches would like more opportunities for professional development directed to their role as coaches. For example, they would like professional development on inquiry-based learning, problem-based learning, the engineering design process, technology, and experiential field trips.

According to coaches, there is also a need for more structure to the STEM program. For example, there needs to be more time and resources to work with teachers. Coaches suggested having specific planning days with each school, ensuring that resources are available to the school. Additionally, there needs to be more structure for the teacher-coach relationship. In many cases, the coaches said that they had to “sell” themselves in order for teachers to want to work with them.

Another recommendation relates to how teachers are selected to work with the STEM Learning Coaches. Coaches suggest that teachers should be allowed to choose whether they want to participate in the STEM program, rather than being selected to participate.
Summary: STEM Learning Coaches were asked about recommendations for moving forward with the implementation of the TDSB STEM strategy. The main recommendations focus on professional development for coaches and creating more structure to the STEM strategy. The recommendations include:

- Better PD sessions for the coaches (inquiry-based learning, problem-based learning, engineering design process, technology, experiential field trips, etc.)
- More time and resources to work with teachers
  - Have specific planning days with each school
  - Ensure that resources are available to schools
  - More structure for the teacher-coach relationship
- Allow teachers to select if they want to participate in the STEM program.

Additional Comments
Overall, the STEM Learning Coaches perceived the STEM program to be very successful, but they thought that it could use some small changes such as more professional development time for coaches and more technology resources. Following are additional comments made by the STEM Learning Coaches.

It's just the beginning of the program. We have only scratched the surface this first year. The real focus for the coming year should be the implementation at the school level to effect pedagogical change.

This probably [has] been the most rewarding and greatest teaching experience in my career.

As a coach, I feel that there is very little time for myself to explore PL or even collaborate with other coaches. I strongly feel that I work with a very dynamic team with diverse strengths and abilities. I wish I had more opportunity to learn more from them.

We need more resources: Apple laptops and iPads. Digital projector, Speakers. We are STEM and we need the tools to support that.

Summary: STEM Learning Coaches were asked if they had any additional comments. Overall, the STEM Learning Coaches perceived the STEM program to be very successful, but saw that the program could use some small changes such as more professional development time for coaches, and the need for more technology resources.
STUDENT RESULTS

Elementary and secondary school students were asked a series of questions about STEM education. Overall, the goal of the survey was twofold: (1) to identify STEM skills and competencies that students have developed through the STEM program, and (2) to better understand students’ interests in STEM careers. The questions covered two main areas: (1) teacher practices in STEM education and (2) 21st century learning skills and competencies, including global learning and use of technology.
OVERALL Summary: Overall, students felt that they have developed their STEM skills and competencies. In fact, a large number of students said that they “loved STEM.” Students believed that STEM education helped with engagement and helped them learn new information. Secondary school students felt that STEM education was relevant and meaningful to their life or future career. Elementary school students felt that STEM classes gave them the opportunity to build things, use technology, and work in groups. Students also felt strongly that the STEM skill they have developed the most is respect, and the area in which they need more development is time management.

Other Important Results:

STEM Skills and Competencies Elementary & Secondary School Students Have Developed:

- Inquiry-based learning: The results showed that students felt that their teachers encouraged them to: ask questions, investigate and explore information, analyze information and think about what they are learning.

- Problem-based learning: Students felt that they were given opportunities for problem-based learning. They were encouraged to: work in small groups, find answers to problems, do experiments, build or create things, ask questions, investigate and explore information, analyze information, and think about what they are learning.

- Collaboration: Students felt they were encouraged to develop their collaboration skills. Students also felt that they were able to work with other students to complete a task.

- Creativity: Students were encouraged to develop their ability to come up with ideas.

- Global Learning: Students felt strongly that teachers did not encourage them to connect with students in different parts of the world.

- Technology: Students felt that teachers encouraged them to use technology to explore information, but were not as encouraging when it came to using technology to share information with others.

- 21st Century Learning: Students both at the elementary and secondary school levels felt strongly that they could respect the differences of their peers. Elementary and secondary school students also revealed that they sometimes struggled with time management.

Differences between Elementary and Secondary School Students STEM Skills:

- Creativity: Elementary school students felt that they can come up with new ideas and different solutions, but secondary school students felt they had more difficulty with this.

- Problem-Based Learning: Elementary school students felt that they were encouraged to do experiments, build or create things more than their secondary school student counterparts.

Secondary school students were ONLY asked about the following:

- Relevance of STEM: Secondary school students felt that STEM education was relevant and meaningful to their life or future career (78% of students strongly agreed or agreed with this statement).

- Students Sense of Belonging: Twenty-nine percent (29%) of secondary school students felt like they were not an important member of the classroom community.

- Feedback about STEM: A large number of students felt that STEM education improved their learning; however, almost 30% of students reported that they were not sure. There was no follow-up question for students who selected “not sure,” so it cannot be ascertained as to why they selected this response.
Overall Study Demographics

In total, 439 students took part in the study, and of this total, 310 of the students were in Grades 3-8 and 129 students were in Grades 9-11. Each student participant completed a survey on STEM education. The student surveys were completed electronically during class time, and the younger students were offered guidance from their teacher in completing the survey.

**Summary:** The study included 439 students in Grades 3-8 and Grades 9-11. There were 310 students from Grades 3-8 and 129 students from Grades 9-11. The majority of elementary school students were in Grade 6 (32%), and the majority of secondary school students were in Grade 9 (65%). Students in Grade 12 did not participate in the study. Elementary and secondary school students were split almost equally among females and males.

Among the elementary school students (Grades 3-8), there were student respondents among all the grades. Students in Grade 6 had the largest representation with 32% of respondents, while the other grades represented about 10-16% of respondents (see Figure 19).

**Figure 19: Grade (Elementary)**

- Grade 6 (100) 32%
- Grade 7 (49) 16%
- Grade 8 (45) 15%
- Grade 3 (43) 14%
- Grade 4 (32) 10%
- Grade 5 (41) 13%

**Figure 20: Grade (Secondary)**

- Grade 9 (81) 65%
- Grade 10 (33) 26%
- Grade 11 (11) 9%

Among secondary school students, not all of the grades were represented. There were no students in Grade 12 who completed the survey. As well, the majority of the secondary school students were in Grade 9, with 65%, followed by 26% in Grade 10 and 9% in Grade 11 (see Figure 20).
The elementary and secondary school students had similar gender identity breakdowns among survey participants and a close to equal split among males and females. For elementary school students, 46% of students were male, 50% were female, and 4% were in the “other” category (see Figures 21 and 22).

Similarly, for secondary school students, 53% of students were male, 42% were female, 1% were trans, 1% were gender-queer, 1% were androgynous, and 3% were “other” (including those who selected all gender identities).

**About You and Your School**

**Teacher Practices**

Students were asked statements about teacher practices on inquiry-based learning, problem-based learning, collaboration, and creativity in the classroom. The overall questions on teacher practice showed similar results among elementary and secondary school students (see Figures 23 and 24). The results indicated that students of all grade levels felt that their teachers encouraged them to come up with ideas, but they did not encourage them to choose their own topics of learning or connect with students in different parts of the world.
Figure 23: Teacher Practices (Elementary)

<table>
<thead>
<tr>
<th>Teacher Practices (27 items Elementary)</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choose the topics we want to learn</td>
<td>16% (49)</td>
<td>15% (46)</td>
<td>13% (40)</td>
<td>24% (75)</td>
<td>19% (58)</td>
<td>13% (40)</td>
</tr>
<tr>
<td>Ask questions about a topic</td>
<td>1% (3)</td>
<td>2% (7)</td>
<td>6% (18)</td>
<td>22% (67)</td>
<td>32% (98)</td>
<td>37% (119)</td>
</tr>
<tr>
<td>Investigate and explore information</td>
<td>2% (5)</td>
<td>3% (10)</td>
<td>5% (16)</td>
<td>17% (51)</td>
<td>39% (118)</td>
<td>34% (105)</td>
</tr>
<tr>
<td>Analyse information</td>
<td>1% (4)</td>
<td>4% (13)</td>
<td>8% (26)</td>
<td>20% (61)</td>
<td>39% (118)</td>
<td>27% (84)</td>
</tr>
<tr>
<td>Think about what we are learning</td>
<td>2% (5)</td>
<td>2% (6)</td>
<td>5% (16)</td>
<td>21% (65)</td>
<td>35% (107)</td>
<td>35% (109)</td>
</tr>
<tr>
<td>Communicate our ideas</td>
<td>3% (8)</td>
<td>3% (10)</td>
<td>7% (22)</td>
<td>15% (46)</td>
<td>34% (105)</td>
<td>38% (117)</td>
</tr>
<tr>
<td>Work in small groups to find answers to problems</td>
<td>2% (5)</td>
<td>2% (6)</td>
<td>6% (19)</td>
<td>22% (67)</td>
<td>32% (98)</td>
<td>37% (115)</td>
</tr>
<tr>
<td>Do experiments, build or create things</td>
<td>2% (6)</td>
<td>4% (12)</td>
<td>6% (19)</td>
<td>15% (46)</td>
<td>26% (79)</td>
<td>48% (146)</td>
</tr>
<tr>
<td>Work with others to complete a task</td>
<td>3% (9)</td>
<td>4% (13)</td>
<td>6% (18)</td>
<td>23% (70)</td>
<td>35% (109)</td>
<td>29% (91)</td>
</tr>
<tr>
<td>Share what we learn with others</td>
<td>2% (7)</td>
<td>5% (14)</td>
<td>11% (35)</td>
<td>23% (72)</td>
<td>33% (103)</td>
<td>25% (77)</td>
</tr>
<tr>
<td>Give feedback to other students</td>
<td>3% (10)</td>
<td>6% (19)</td>
<td>8% (25)</td>
<td>24% (73)</td>
<td>31% (96)</td>
<td>27% (83)</td>
</tr>
<tr>
<td>Come up with ideas</td>
<td>1% (3)</td>
<td>1% (4)</td>
<td>6% (17)</td>
<td>14% (44)</td>
<td>37% (112)</td>
<td>41% (126)</td>
</tr>
<tr>
<td>Think about new and different ways to solve problems</td>
<td>1% (3)</td>
<td>2% (5)</td>
<td>7% (22)</td>
<td>21% (63)</td>
<td>34% (103)</td>
<td>36% (111)</td>
</tr>
<tr>
<td>Use technology to explore information</td>
<td>2% (6)</td>
<td>4% (12)</td>
<td>9% (27)</td>
<td>23% (70)</td>
<td>28% (88)</td>
<td>34% (106)</td>
</tr>
<tr>
<td>Use technology to share information with others</td>
<td>7% (22)</td>
<td>10% (30)</td>
<td>14% (44)</td>
<td>21% (65)</td>
<td>25% (76)</td>
<td>23% (70)</td>
</tr>
<tr>
<td>Do research about different places and cultures around the world</td>
<td>5% (16)</td>
<td>7% (20)</td>
<td>8% (25)</td>
<td>25% (75)</td>
<td>28% (86)</td>
<td>27% (83)</td>
</tr>
<tr>
<td>Discuss topics and issues in our world (e.g., current events)</td>
<td>3% (9)</td>
<td>4% (12)</td>
<td>9% (27)</td>
<td>25% (76)</td>
<td>28% (86)</td>
<td>31% (95)</td>
</tr>
<tr>
<td>Connect with students in different parts of the world</td>
<td>26% (79)</td>
<td>12% (36)</td>
<td>13% (40)</td>
<td>16% (50)</td>
<td>17% (52)</td>
<td>15% (47)</td>
</tr>
<tr>
<td>Ask questions</td>
<td>1% (2)</td>
<td>2% (6)</td>
<td>4% (13)</td>
<td>15% (45)</td>
<td>32% (96)</td>
<td>46% (136)</td>
</tr>
<tr>
<td>Investigate and explore information</td>
<td>0% (1)</td>
<td>2% (7)</td>
<td>5% (14)</td>
<td>16% (49)</td>
<td>35% (105)</td>
<td>41% (122)</td>
</tr>
<tr>
<td>Think about what I am learning</td>
<td>1% (2)</td>
<td>1% (4)</td>
<td>6% (15)</td>
<td>14% (41)</td>
<td>34% (102)</td>
<td>43% (128)</td>
</tr>
<tr>
<td>Analyse information</td>
<td>1% (3)</td>
<td>3% (9)</td>
<td>7% (21)</td>
<td>21% (63)</td>
<td>31% (92)</td>
<td>37% (109)</td>
</tr>
<tr>
<td>Come up with new ideas</td>
<td>1% (4)</td>
<td>1% (4)</td>
<td>4% (13)</td>
<td>15% (44)</td>
<td>33% (99)</td>
<td>45% (134)</td>
</tr>
<tr>
<td>Find new ways of doing things</td>
<td>1% (4)</td>
<td>2% (5)</td>
<td>6% (18)</td>
<td>17% (51)</td>
<td>34% (99)</td>
<td>40% (116)</td>
</tr>
<tr>
<td>Come up with new and different solutions</td>
<td>1% (3)</td>
<td>2% (7)</td>
<td>6% (18)</td>
<td>21% (62)</td>
<td>34% (100)</td>
<td>36% (107)</td>
</tr>
<tr>
<td>Communicate my ideas</td>
<td>2% (5)</td>
<td>3% (10)</td>
<td>5% (14)</td>
<td>20% (58)</td>
<td>34% (100)</td>
<td>37% (109)</td>
</tr>
<tr>
<td>Work with other students to complete a task</td>
<td>2% (7)</td>
<td>1% (3)</td>
<td>4% (12)</td>
<td>15% (44)</td>
<td>37% (109)</td>
<td>41% (120)</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td><strong>3% (280)</strong></td>
<td><strong>4% (329)</strong></td>
<td><strong>7% (599)</strong></td>
<td><strong>19% (1583)</strong></td>
<td><strong>32% (2602)</strong></td>
<td><strong>34% (2801)</strong></td>
</tr>
</tbody>
</table>
Both elementary and secondary school students felt that the teachers in their school did not encourage them to choose their own topics of learning. In fact, 16% of elementary school students and 11% of secondary school students strongly disagreed with the statement, “in my school, teachers encourage students to choose the topics we want to learn.” In terms of teaching practices, this statement had one of the highest levels of disagreement among students.

In addition, students in both elementary and secondary schools overwhelmingly agreed that teachers in their school did not encourage them to connect with students in different parts of the world. Fifty-one percent (51%) of elementary school students and 66% of secondary school students “strongly disagreed”, “disagreed” or “somewhat disagreed” with the statement, “in my school, teachers encourage students to connect with students in different parts of the world.”

<table>
<thead>
<tr>
<th>Teacher Practices (29 items Secondary)</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choose the topics we want to learn</td>
<td>11% (14)</td>
<td>16% (20)</td>
<td>20% (26)</td>
<td>19% (25)</td>
<td>25% (32)</td>
<td>9% (12)</td>
</tr>
<tr>
<td>Ask questions about a topic</td>
<td>2% (2)</td>
<td>1% (1)</td>
<td>5% (7)</td>
<td>22% (28)</td>
<td>48% (62)</td>
<td>22% (29)</td>
</tr>
<tr>
<td>Investigate and explore information</td>
<td>1% (1)</td>
<td>4% (5)</td>
<td>8% (10)</td>
<td>22% (28)</td>
<td>46% (59)</td>
<td>20% (26)</td>
</tr>
<tr>
<td>Analyse information</td>
<td>1% (1)</td>
<td>2% (2)</td>
<td>9% (12)</td>
<td>24% (31)</td>
<td>47% (61)</td>
<td>17% (22)</td>
</tr>
<tr>
<td>Think about what we are learning</td>
<td>2% (3)</td>
<td>5% (6)</td>
<td>9% (11)</td>
<td>25% (32)</td>
<td>40% (51)</td>
<td>20% (26)</td>
</tr>
<tr>
<td>Communicate our ideas</td>
<td>2% (3)</td>
<td>4% (5)</td>
<td>8% (10)</td>
<td>26% (33)</td>
<td>41% (52)</td>
<td>20% (25)</td>
</tr>
<tr>
<td>Work in small groups to find answers to problems</td>
<td>2% (2)</td>
<td>6% (8)</td>
<td>14% (18)</td>
<td>20% (26)</td>
<td>40% (51)</td>
<td>18% (23)</td>
</tr>
<tr>
<td>Do experiments, build or create things</td>
<td>5% (6)</td>
<td>6% (8)</td>
<td>14% (18)</td>
<td>28% (36)</td>
<td>30% (39)</td>
<td>17% (22)</td>
</tr>
<tr>
<td>Work with others to complete a task</td>
<td>3% (4)</td>
<td>5% (6)</td>
<td>9% (12)</td>
<td>33% (42)</td>
<td>36% (47)</td>
<td>14% (18)</td>
</tr>
<tr>
<td>Share what we learn with others</td>
<td>2% (2)</td>
<td>5% (6)</td>
<td>12% (15)</td>
<td>31% (40)</td>
<td>33% (43)</td>
<td>18% (23)</td>
</tr>
<tr>
<td>Give feedback to other students</td>
<td>2% (3)</td>
<td>5% (6)</td>
<td>16% (21)</td>
<td>31% (40)</td>
<td>33% (43)</td>
<td>12% (16)</td>
</tr>
<tr>
<td>Come up with ideas</td>
<td>2% (2)</td>
<td>4% (5)</td>
<td>5% (7)</td>
<td>30% (38)</td>
<td>36% (46)</td>
<td>23% (30)</td>
</tr>
<tr>
<td>Think about new and different ways to solve problems</td>
<td>2% (2)</td>
<td>5% (6)</td>
<td>10% (13)</td>
<td>31% (39)</td>
<td>35% (45)</td>
<td>17% (22)</td>
</tr>
<tr>
<td>Use technology to explore information</td>
<td>2% (3)</td>
<td>2% (3)</td>
<td>8% (10)</td>
<td>31% (40)</td>
<td>35% (45)</td>
<td>22% (28)</td>
</tr>
<tr>
<td>Use technology to share information with others</td>
<td>4% (5)</td>
<td>6% (8)</td>
<td>14% (18)</td>
<td>30% (38)</td>
<td>29% (37)</td>
<td>17% (22)</td>
</tr>
<tr>
<td>Do research about different places and cultures around the world</td>
<td>8% (10)</td>
<td>9% (11)</td>
<td>20% (26)</td>
<td>35% (45)</td>
<td>23% (30)</td>
<td>5% (7)</td>
</tr>
<tr>
<td>Discuss topics and issues in our world (e.g., current events)</td>
<td>6% (8)</td>
<td>10% (13)</td>
<td>15% (19)</td>
<td>36% (46)</td>
<td>20% (26)</td>
<td>8% (10)</td>
</tr>
<tr>
<td>Connect with students in different parts of the world</td>
<td>27% (35)</td>
<td>20% (26)</td>
<td>19% (24)</td>
<td>21% (27)</td>
<td>11% (14)</td>
<td>2% (3)</td>
</tr>
<tr>
<td>Ask questions</td>
<td>3% (4)</td>
<td>2% (2)</td>
<td>9% (12)</td>
<td>30% (39)</td>
<td>34% (44)</td>
<td>21% (27)</td>
</tr>
<tr>
<td>Investigate and explore information</td>
<td>2% (3)</td>
<td>1% (1)</td>
<td>4% (5)</td>
<td>27% (35)</td>
<td>44% (56)</td>
<td>22% (28)</td>
</tr>
<tr>
<td>Think about what I am learning</td>
<td>2% (3)</td>
<td>3% (4)</td>
<td>9% (11)</td>
<td>23% (30)</td>
<td>39% (50)</td>
<td>24% (31)</td>
</tr>
<tr>
<td>Analyse information</td>
<td>3% (4)</td>
<td>2% (2)</td>
<td>5% (6)</td>
<td>30% (39)</td>
<td>41% (53)</td>
<td>19% (24)</td>
</tr>
<tr>
<td>Come up with new ideas</td>
<td>2% (3)</td>
<td>4% (5)</td>
<td>9% (11)</td>
<td>28% (36)</td>
<td>38% (49)</td>
<td>19% (25)</td>
</tr>
<tr>
<td>Find new ways of doing things</td>
<td>2% (3)</td>
<td>5% (7)</td>
<td>9% (11)</td>
<td>22% (29)</td>
<td>44% (57)</td>
<td>17% (22)</td>
</tr>
<tr>
<td>Come up with new and different solutions</td>
<td>5% (6)</td>
<td>3% (4)</td>
<td>11% (14)</td>
<td>27% (35)</td>
<td>39% (50)</td>
<td>16% (20)</td>
</tr>
<tr>
<td>Communicate my ideas</td>
<td>3% (4)</td>
<td>5% (7)</td>
<td>5% (7)</td>
<td>30% (38)</td>
<td>38% (49)</td>
<td>18% (23)</td>
</tr>
<tr>
<td>Work with other students to complete a task</td>
<td>2% (2)</td>
<td>3% (4)</td>
<td>6% (8)</td>
<td>22% (28)</td>
<td>44% (57)</td>
<td>23% (30)</td>
</tr>
<tr>
<td>Share what we learn with others</td>
<td>2% (2)</td>
<td>2% (2)</td>
<td>9% (12)</td>
<td>27% (35)</td>
<td>43% (55)</td>
<td>18% (23)</td>
</tr>
<tr>
<td>Give feedback to other students</td>
<td>2% (2)</td>
<td>4% (5)</td>
<td>13% (17)</td>
<td>29% (38)</td>
<td>39% (50)</td>
<td>13% (17)</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>4% (142)</td>
<td>5% (188)</td>
<td>10% (89)</td>
<td>27% (1016)</td>
<td>36% (1860)</td>
<td>17% (634)</td>
</tr>
</tbody>
</table>

![Figure 24: Teacher Practices (Secondary)](image_url)
Summary: Elementary and secondary school students felt very positive about their teachers’ practices in inquiry-based learning, problem-based learning, collaboration and creativity in the classroom. The results showed that students of all grade levels reported that teachers in their school encouraged them to come up with ideas (41% of elementary school students and 23% of secondary school students strongly agreed). Students also felt that teachers did not support students to choose their own topics of learning and give them opportunities to connect with students in different parts of the world.

Inquiry-based Learning

Inquiry-based learning is a student-centered teaching technique where students make investigations, look for information, and ask questions (Ontario Ministry of Education, 2013), and has become a major part of the educational landscape in Canada. Students were asked about inquiry-based learning in their classrooms. Overwhelmingly, students of all grade levels felt strongly that teachers in their school encouraged inquiry-based learning. Students agreed that their teachers encouraged them to: (1) ask questions about a topic, (2) investigate and explore information, (3) analyze information, and (4) think about what they are learning. However, students did identify one area of inquiry-based learning they felt was not strongly encouraged and that was being able to choose their own topics of learning (see Figures 25 and 26).

Figure 25: Teacher Practices: Inquiry-based Learning (Elementary)
Elementary and secondary school students felt strongly that the teachers in their school encouraged inquiry-based learning. For all but one of the statements on inquiry-based learning, students had at least 84% agreement with the statements. The breakdowns were as follows: students strongly agreed, agreed, or somewhat agreed that their teachers encouraged them to: (1) ask questions about a topic (91% for elementary, 92% for secondary), (2) investigate and explore information (90% for elementary, 88% for secondary), (3) analyze information (86% for elementary, 88% for secondary), and (4) think about what they are learning (91% for elementary and 84% for secondary).

One notable finding on inquiry-based learning was that students felt that teachers in their school did not encourage them to choose their own topics of learning. This was mentioned earlier as one of the important findings on teacher practices from this study. This statement had the second highest percentage of strongly disagrees, disagrees, or somewhat disagrees among all study questions (44% for elementary and 47% for secondary).

For elementary school students, there were two statistically significant results related to inquiry-based learning in relation to students’ ability to ask questions and analyze information. There was a significantly higher percentage of female students who only somewhat agreed or somewhat disagreed that they were confident in their ability to ask questions as compared to male students. The results were as follows: 30% of females somewhat agreed or disagreed that “they are able to ask questions” compared to 6% of males. On the other hand, female students agreed much more strongly than male students that they can analyze information. Specifically, 34% of female students strongly agreed or agreed that they could analyze data, in comparison to 23% of male students.
Problem-based Learning

Problem-based learning is a student-centered teaching approach where students solve complex, real-world problems in small groups through case studies (Barrows, 1996). The goal of problem-based learning is to develop students’ intrinsic interest, develop a deeper understanding and create a greater sense of ownership of learning (Barrows, 1996). Students were asked two statements about their experience with problem-based learning at their school. The two statements were “in my school, teachers encourage students to: (1) work in small groups to find answers to problems” and (2) “do experiments, build or create things.” Overall, elementary and secondary school students agreed that they were given opportunities for problem-based learning in the classroom.

Elementary and secondary school students agreed that problem-based learning was encouraged in their school. There was more than 88% agreement among elementary school students and 75% agreement among secondary school students with the statement, “in my school, teachers encourage students to do experiments, build or create things.” In addition to that, there was 90% agreement among elementary school students and 78% among secondary school students with the statement, “in my school, teachers encourage students to work in small groups to find answers to problems.”

However, the results show an important difference between elementary and secondary school students and this was in regards to the encouragement of teachers to do experiments, build or create things. Elementary school students felt that they were encouraged to do experiments, build or create things more than their secondary school student counterparts. In fact, 48% of elementary schools students strongly agreed that teachers encouraged them to do experiments, build or create things, compared to 17% of secondary school students. For elementary school students, this statement elicited the highest agreement among all of the questions regarding teacher practices. This may highlight that problem-based learning is not as widespread at the secondary school level (see Figures 27 and 28).

Summary: Elementary and secondary school students presented with strong overall viewpoints on inquiry-based learning. The results showed that students felt that their teachers encouraged them to: ask questions about a topic, investigate and explore information, analyze information and think about what they are learning. However, less than half of the students felt they were not encouraged to choose their own topics of learning.
Students were asked six different statements about collaboration. The overall collaboration measures between elementary and secondary school students reveal important findings.

Elementary and secondary school students had very high agreement with all the statements about collaboration. Among elementary and secondary school students, all of the statements but one had at least 80% agreement.

A driving statement for collaboration was in regards to working with other students to complete a task. Ninety-three percent (93%) of elementary school students and 89% of secondary school students strongly agreed, agreed, or somewhat agreed with the statement, “I am able to work with others to complete a task.” Among all of the statements on collaboration, this statement had the highest student agreement.

There was one statement with less than 80% agreement which was “in my school, teachers encourage students to give feedback to other students”, with 77% of secondary school students agreeing (see Figures 29 and 30).
So mewhat

Table:<br>

<table>
<thead>
<tr>
<th>Teacher Practices: Collaboration (Elementary)</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communicate our ideas</td>
<td>11%</td>
<td>34%</td>
<td>20%</td>
<td>11%</td>
<td>2%</td>
</tr>
<tr>
<td>Work with others to complete a task</td>
<td>11%</td>
<td>34%</td>
<td>20%</td>
<td>11%</td>
<td>2%</td>
</tr>
<tr>
<td>Share what we learn with others</td>
<td>11%</td>
<td>34%</td>
<td>20%</td>
<td>11%</td>
<td>2%</td>
</tr>
<tr>
<td>Give feedback to other students</td>
<td>11%</td>
<td>34%</td>
<td>20%</td>
<td>11%</td>
<td>2%</td>
</tr>
<tr>
<td>Communicate my ideas</td>
<td>11%</td>
<td>34%</td>
<td>20%</td>
<td>11%</td>
<td>2%</td>
</tr>
<tr>
<td>Work with other students to complete a task</td>
<td>11%</td>
<td>34%</td>
<td>20%</td>
<td>11%</td>
<td>2%</td>
</tr>
<tr>
<td>Overall</td>
<td>11%</td>
<td>34%</td>
<td>20%</td>
<td>11%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Note: * Refers to the question “In my school, teachers encourage students to ...”
** Refers to the question on the survey “I am able to...”

Summary: Overall, elementary and secondary school students had very high agreement with all the statements about collaboration. Among elementary and secondary school students, all of the statements about teacher practices regarding collaboration had at least 80% agreement. A driving statement for collaboration was in regards to working with other students to complete a task. This is because 93% of elementary school students and 89% of secondary school students strongly agreed, agreed or somewhat agreed with this statement, and had the highest agreement among all of the statements about collaboration.

Creativity

Teachers can play a significant part in nurturing students’ creativity and innovative thinking and the importance of employing innovative teaching to increase students’ creativity has been acknowledged in the literature (Ayverdi et al., 2012; Beghetto, 2007; Esquivel, 1995; National Advisory Committee on Creative and Cultural Education [NACCCE], 1999; Sharp, 2004; Simplicio, 2000). Students were asked two statements about teacher practices in regards to fostering creativity in the classroom. Specifically, they were asked whether teachers in their school encouraged students to: (1) “come up with ideas” and (2) “think about new and different ways to solve problems.” The results showed important similarities and differences among elementary and secondary school students. Both elementary and secondary school students felt strongly that the teachers in their school encouraged them to come up with ideas. This statement received the
highest percentage of strongly agrees for secondary school students (23%) and the second highest percentage of strongly agrees for elementary school students (41%).

Students were also asked questions relating to their self-efficacy. Elementary and secondary school students differed in their perceptions of their ability to come up with new and different solutions. A large percentage of secondary school students felt that they were not able to come up with new ideas and different solutions. In fact, 19% of secondary school students strongly disagreed, disagreed, or somewhat disagreed with the statement, “I am able to come up with new and different solutions.” This was the highest percentage of disagreement among secondary school students among all of the questions asking about students’ perceived skills. In comparison, only 9% of elementary school students felt that they were unable to come up with new and different solutions.

Other differences among elementary and secondary school students are highlighted here. For all the statements asking about students’ perceived skills - “I am able to (1) come up with new ideas, (2) find new ways of doing things, and (3) come up with new and different solutions” – less than 10% for elementary school students disagreed, compared to secondary school students with between 11-19% in disagreement (see Figures 31 and 32).

**Figure 31: Teacher Practices: Creativity (Elementary)**

<table>
<thead>
<tr>
<th>Teacher Practices: Creativity (Elementary)</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Come up with ideas</td>
<td>1% (3)</td>
<td>1% (4)</td>
<td>6% (17)</td>
<td>37% (112)</td>
<td>41% (126)</td>
<td></td>
</tr>
<tr>
<td>Think about new and different ways to solve problems</td>
<td>1% (3)</td>
<td>2% (5)</td>
<td>7% (22)</td>
<td>34% (103)</td>
<td>36% (111)</td>
<td></td>
</tr>
<tr>
<td>Come up with new ideas</td>
<td>1% (4)</td>
<td>1% (4)</td>
<td>4% (13)</td>
<td>33% (99)</td>
<td>45% (134)</td>
<td></td>
</tr>
<tr>
<td>Find new ways of doing things</td>
<td>1% (4)</td>
<td>2% (5)</td>
<td>6% (18)</td>
<td>34% (99)</td>
<td>40% (116)</td>
<td></td>
</tr>
<tr>
<td>Come up with new and different solutions</td>
<td>1% (3)</td>
<td>2% (7)</td>
<td>6% (18)</td>
<td>34% (120)</td>
<td>36% (107)</td>
<td></td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>1% (17)</td>
<td>2% (25)</td>
<td>6% (88)</td>
<td>34% (513)</td>
<td>40% (594)</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 32: Teacher Practices: Creativity (Secondary)**

<table>
<thead>
<tr>
<th>Teacher Practices: Creativity (Secondary)</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Come up with ideas</td>
<td>2% (2)</td>
<td>4% (5)</td>
<td>5% (7)</td>
<td>30% (38)</td>
<td>30% (46)</td>
<td>23% (30)</td>
</tr>
<tr>
<td>Think about new and different ways to solve problems</td>
<td>2% (2)</td>
<td>5% (6)</td>
<td>10% (13)</td>
<td>35% (45)</td>
<td>17% (22)</td>
<td></td>
</tr>
<tr>
<td>Come up with new ideas</td>
<td>2% (3)</td>
<td>4% (5)</td>
<td>9% (11)</td>
<td>28% (36)</td>
<td>38% (49)</td>
<td>19% (25)</td>
</tr>
<tr>
<td>Find new ways of doing things</td>
<td>2% (3)</td>
<td>5% (7)</td>
<td>9% (11)</td>
<td>22% (29)</td>
<td>44% (57)</td>
<td>17% (22)</td>
</tr>
<tr>
<td>Come up with new and different solutions</td>
<td>5% (6)</td>
<td>3% (4)</td>
<td>11% (14)</td>
<td>27% (35)</td>
<td>39% (50)</td>
<td>16% (20)</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>2% (16)</td>
<td>4% (27)</td>
<td>9% (56)</td>
<td>28% (177)</td>
<td>38% (247)</td>
<td>19% (119)</td>
</tr>
</tbody>
</table>
Students were asked three different statements about global learning. The results uncovered important findings about global learning and teacher practices that encouraged students to connect with students in different parts of the world.

Students both at the elementary and secondary school level felt strongly that in their school, teachers did not encourage them to connect with students in different parts of the world. The statement “in my school, teachers encourage student to connect with students in different parts of the world” elicited the largest percentage of strongly disagrees, disagrees, or somewhat disagrees compared to all of the other questions on teacher practices. In fact, 51% of elementary secondary students and 66% of secondary school students strongly disagreed, disagreed, or somewhat disagreed with this statement.

In addition to this, students were asked to rate the following two other statements about global learning: “in my school, teachers encourage students to (1) “do research about different places and cultures around the world” and (2) “discuss topics and issues in our world.” These two statements had different results among elementary and secondary school students. Elementary school students had quite strong agreement with these statements, with at least 80% in agreement, however, secondary school students had much less agreement ranging from 64-69%. Thirty-six percent (36%) of secondary school students disagreed with the statement, “in my school, teachers encourage students to do research about different places and cultures around the world”, and 31% of secondary school students disagreed with the statement, “in my school, teachers encourage students to discuss topics and issues in our world.” The responses to these statements suggested important differences in teacher practices in global learning at the elementary and secondary levels (see Figures 33 and 34).

**Summary:** The results showed important similarities and differences among elementary and secondary school students. Both elementary and secondary school students felt strongly that the teachers in their school encouraged them to come up with ideas. This statement had the highest level of strong agreement for secondary school students (23% strongly agreed) and the second highest level of strong agreement for elementary school students (41% strongly agreed). However, a notable difference among elementary and secondary school students was in terms of students’ perceptions of self-efficacy. That is, a large percentage of secondary school students felt that they were not able to come up with new ideas and different solutions (19%), while only 9% of elementary school students had this perception.

**Global Learning**

Students were asked three different statements about global learning. The results uncovered important findings about global learning and teacher practices that encouraged students to connect with students in different parts of the world.

Students both at the elementary and secondary school level felt strongly that in their school, teachers did not encourage them to connect with students in different parts of the world. The statement “in my school, teachers encourage students to connect with students in different parts of the world” elicited the largest percentage of strongly disagrees, disagrees, or somewhat disagrees compared to all of the other questions on teacher practices. In fact, 51% of elementary secondary students and 66% of secondary school students strongly disagreed, disagreed, or somewhat disagreed with this statement.

In addition to this, students were asked to rate the following two other statements about global learning: “in my school, teachers encourage students to (1) “do research about different places and cultures around the world” and (2) “discuss topics and issues in our world.” These two statements had different results among elementary and secondary school students. Elementary school students had quite strong agreement with these statements, with at least 80% in agreement, however, secondary school students had much less agreement ranging from 64-69%. Thirty-six percent (36%) of secondary school students disagreed with the statement, “in my school, teachers encourage students to do research about different places and cultures around the world”, and 31% of secondary school students disagreed with the statement, “in my school, teachers encourage students to discuss topics and issues in our world.” The responses to these statements suggested important differences in teacher practices in global learning at the elementary and secondary levels (see Figures 33 and 34).
Summary: The results uncovered important findings about global learning and teacher practices that encouraged students to connect with students in different parts of the world. Students both at the elementary and secondary school level felt strongly that in their school, teachers did not encourage them to connect with students in different parts of the world. This statement elicited the largest proportion of strongly disagrees, disagrees, or somewhat disagrees compared to all of the other questions on teacher practices. Fifty-one percent (51%) of elementary school students and 66% of secondary school students strongly disagreed, disagreed, or somewhat disagreed with this statement. Other notable findings on global learning were that secondary school students had high disagreement with the other statements asking about teacher practice and global learning, but elementary school students did not.

Using Technology

The TDSB currently nurtures creativity and innovation through many pockets of innovative programs in educational technology (Sinay, 2014; Sinay et al., 2015). Students were asked to rate two statements regarding teacher practices and technology. The statements were as follows: “In my school, teachers encourage students to (1) “use technology to explore information” and (2) use “technology to share information with others.” Overall, elementary and secondary school students had similar viewpoints on teachers’ practices and technology. Students felt that teachers encouraged them to use technology to explore information, but were not as encouraging when it came to using technology to share information with others.

Elementary and secondary school students both felt that teachers in their schools encouraged them to use technology to explore information. In fact, 85% of elementary school students and 88% of secondary school students strongly agreed, agreed or
somewhat agreed with the statement, “in my school, teachers encourage students to use technology to explore information.”

On the other hand, elementary and secondary school students also felt that teachers were not as encouraging when it came to using technology to share information with others. The statement “in my school, teachers encourage students to use technology to share information with others,” had the second highest percentage of students who strongly disagreed, disagreed or somewhat disagreed (31% for elementary and 24% for secondary) (see Figures 35 and 36).

Some students would like to see even more technology in the classroom, and responded to the additional questions section of the survey by saying “I would have liked to learn C# [programming language] in computer science, it would be a lot more interesting.”

**Summary:** Overall, elementary and secondary school students had similar viewpoints on teachers’ practices and technology. Students felt that teachers encouraged them to use technology to explore information, but were not as encouraging when it came to using technology to share information with others. The statement “in my school, teachers encourage students to use technology to share information with others,” had the second highest percentage of students who strongly disagreed, disagreed, or somewhat disagreed (31% for elementary and 24% for secondary).

**21st Century Learning**

Twenty-first (21st) century competencies are fundamental skills which students should have to be prepared for the future. Twenty-first century competencies include creativity and innovation, critical thinking, collaboration, effective communication, building character, culture and ethical citizenship, and comfort with technology (C21
Canada, 2012). Students were asked to rate 11 statements about their 21st-century learning skills and competencies (see Figures 37 and 38). The results revealed important findings about students’ ability to respect differences, their struggles with time management, and leading others to accomplish goals.

Students felt strongly that they could respect the differences of their peers. Ninety-three percent (93%) of elementary school students strongly agreed, agreed, or somewhat agreed with the statement, “I respect all children my age even if they are different from me”. Similarly, when secondary school students were asked, “I am confident I can respect the differences of my peers” and “I am confident I can work well with students from different backgrounds”, 95% were in agreement.

On the other hand, students also reported that they sometimes struggled with time management. Secondary school students showed the highest level of disagreement with the statement, “I am confident I can manage my time wisely when working on my own,” with 21% of secondary school students strongly disagreeing, disagreeing, or somewhat disagreeing with the statement. In the same way, elementary school students demonstrated that time management skills were sometimes a challenge. The question with the highest level of disagreement among elementary school students was, “When I have a lot of homework, I can choose what needs to be done first,” with 16% of elementary school students strongly disagreeing, disagreeing, or somewhat disagreeing with the statement.

There was also one statistically significant result between male and female elementary school students in regards to helping others. Female students were more likely to try to help others than male students. Forty-three percentage (43%) of females strongly agreed or agreed that “I try to help other children my age” compared to only 32% of males.
**Figure 37: STEM Skills and Competences: 21st Century Learning (Elementary)**

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can lead others to reach a goal.</td>
<td>4% (11)</td>
<td>2% (6)</td>
<td>9% (28)</td>
<td>29% (89)</td>
<td>32% (99)</td>
<td>24% (74)</td>
</tr>
<tr>
<td>I like to help others do their best.</td>
<td>2% (7)</td>
<td>2% (7)</td>
<td>5% (15)</td>
<td>19% (57)</td>
<td>35% (106)</td>
<td>37% (114)</td>
</tr>
<tr>
<td>In school and at home, I can do things well.</td>
<td>1% (4)</td>
<td>1% (3)</td>
<td>7% (20)</td>
<td>18% (54)</td>
<td>39% (119)</td>
<td>35% (106)</td>
</tr>
<tr>
<td>I respect all children my age even if they are different from me.</td>
<td>2% (6)</td>
<td>0% (1)</td>
<td>5% (14)</td>
<td>18% (55)</td>
<td>28% (84)</td>
<td>48% (145)</td>
</tr>
<tr>
<td>I try to help other children my age.</td>
<td>1% (4)</td>
<td>1% (3)</td>
<td>5% (14)</td>
<td>18% (55)</td>
<td>36% (109)</td>
<td>39% (117)</td>
</tr>
<tr>
<td>When I make decisions, I think about what is good for other people.</td>
<td>2% (5)</td>
<td>4% (11)</td>
<td>7% (22)</td>
<td>24% (73)</td>
<td>33% (102)</td>
<td>30% (92)</td>
</tr>
<tr>
<td>When things do not go how I want, I can change my actions for the better.</td>
<td>(0)</td>
<td>2% (6)</td>
<td>11% (33)</td>
<td>23% (69)</td>
<td>35% (106)</td>
<td>30% (91)</td>
</tr>
<tr>
<td>I can make my own goals for learning.</td>
<td>2% (7)</td>
<td>2% (5)</td>
<td>8% (24)</td>
<td>16% (49)</td>
<td>35% (108)</td>
<td>37% (114)</td>
</tr>
<tr>
<td>I can use my time wisely when working on my own.</td>
<td>2% (5)</td>
<td>3% (8)</td>
<td>8% (25)</td>
<td>19% (57)</td>
<td>35% (107)</td>
<td>34% (102)</td>
</tr>
<tr>
<td>When I have a lot of homework, I can choose what needs to be done first.</td>
<td>4% (11)</td>
<td>4% (13)</td>
<td>8% (24)</td>
<td>14% (42)</td>
<td>27% (84)</td>
<td>43% (132)</td>
</tr>
<tr>
<td>I can work well with other students, even if they are different from me.</td>
<td>3% (9)</td>
<td>2% (7)</td>
<td>6% (17)</td>
<td>17% (52)</td>
<td>30% (93)</td>
<td>42% (127)</td>
</tr>
<tr>
<td>Overall</td>
<td>2% (69)</td>
<td>2% (70)</td>
<td>7% (236)</td>
<td>19% (652)</td>
<td>33% (1117)</td>
<td>36% (1214)</td>
</tr>
</tbody>
</table>

**Figure 38: STEM Skills and Competences: 21st Century Learning (Secondary)**

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am confident I can lead others to accomplish a goal.</td>
<td>5% (6)</td>
<td>4% (5)</td>
<td>11% (14)</td>
<td>35% (45)</td>
<td>25% (32)</td>
<td>20% (25)</td>
</tr>
<tr>
<td>I am confident I can encourage others to do their best.</td>
<td>2% (3)</td>
<td>2% (3)</td>
<td>14% (18)</td>
<td>26% (33)</td>
<td>35% (44)</td>
<td>26% (32)</td>
</tr>
<tr>
<td>I am confident I can produce high quality work.</td>
<td>3% (4)</td>
<td>4% (5)</td>
<td>6% (8)</td>
<td>28% (35)</td>
<td>37% (46)</td>
<td>22% (28)</td>
</tr>
<tr>
<td>I am confident I can respect the differences of my peers.</td>
<td>2% (2)</td>
<td>1% (1)</td>
<td>2% (3)</td>
<td>17% (22)</td>
<td>44% (56)</td>
<td>35% (44)</td>
</tr>
<tr>
<td>I am confident I can help my peers.</td>
<td>2% (2)</td>
<td>5% (6)</td>
<td>8% (10)</td>
<td>24% (31)</td>
<td>38% (48)</td>
<td>24% (30)</td>
</tr>
<tr>
<td>I am confident I can include others’ perspectives when making decisions.</td>
<td>1% (1)</td>
<td>1% (1)</td>
<td>9% (12)</td>
<td>21% (27)</td>
<td>46% (58)</td>
<td>22% (28)</td>
</tr>
<tr>
<td>I am confident I can make changes when things do not go as planned.</td>
<td>2% (3)</td>
<td>6% (8)</td>
<td>6% (8)</td>
<td>20% (26)</td>
<td>39% (49)</td>
<td>26% (33)</td>
</tr>
<tr>
<td>I am confident I can set my own learning goals.</td>
<td>2% (2)</td>
<td>6% (7)</td>
<td>8% (10)</td>
<td>28% (35)</td>
<td>37% (47)</td>
<td>20% (26)</td>
</tr>
<tr>
<td>I am confident I can manage my time wisely when working on my own.</td>
<td>6% (8)</td>
<td>3% (4)</td>
<td>12% (15)</td>
<td>32% (41)</td>
<td>28% (35)</td>
<td>19% (24)</td>
</tr>
<tr>
<td>When I have many assignments, I can choose which ones need to be done first.</td>
<td>6% (7)</td>
<td>2% (3)</td>
<td>2% (2)</td>
<td>22% (27)</td>
<td>40% (50)</td>
<td>29% (36)</td>
</tr>
<tr>
<td>I am confident I can work well with students from different backgrounds.</td>
<td>1% (1)</td>
<td>4% (5)</td>
<td>0% (0)</td>
<td>17% (21)</td>
<td>37% (47)</td>
<td>42% (58)</td>
</tr>
<tr>
<td>Overall</td>
<td>3% (39)</td>
<td>3% (48)</td>
<td>7% (100)</td>
<td>25% (342)</td>
<td>37% (512)</td>
<td>25% (353)</td>
</tr>
</tbody>
</table>

**Summary:** The results uncovered important findings about 21st century learning, including students’ ability to respect differences, their struggles with time management and leading others to accomplish a goal. Students both at the elementary and secondary school levels felt strongly that they could respect the differences of their peers. However, elementary and secondary school students also revealed that they sometimes struggled with time management. For example, secondary school students showed the highest level of disagreement with the statement, “I am confident I can manage my time wisely when working on my own,” with 21% of secondary school students strongly disagreeing, disagreeing, or somewhat disagreeing with the statement. There was also one statistically significant result between male and female students regarding helping others. Female students were more likely to try to help others than male students.

**STEM Skills and Competencies**

STEM education includes Science, Technology, Engineering, and Mathematics education and allows for students to build their skills and competencies through rich tasks and innovative thinking processes. Students both at the elementary and secondary school
levels were asked 11 statements and one open-ended question about STEM education. Overall, students of all grade levels felt that they had developed the necessary STEM skills and competencies. Additionally, a large number of students said that they enjoyed STEM education.

Overall, students at the elementary and secondary school levels showed very high agreement with the statements on STEM skills and competencies. For elementary school students, overall agreement ranged from 84-93% among the 11 statements, and for secondary school students, overall agreement ranged from 79-95%. There was also a moderate sized group of elementary school students (24 students), who said that they loved everything about STEM.

Based on student responses to the open-ended question, students of all grade levels believed that STEM education helped with engagement and helped them learn new information. Secondary school students felt that STEM education was relevant and meaningful to their life or future career. Elementary school students felt that STEM classes gave them the opportunity to build things, use technology, and work in groups.

Students also felt strongly that the STEM skill they had developed the most was respect. The statement that elicited the highest overall agreement had to do with respecting differences. The statement “I respect all children my age even if they are different from me” tied for the highest percentage of strongly agrees, agrees or somewhat agrees among elementary school students, and for secondary school students the statement, “I am a confident I can respect the differences of my peers” also elicited the highest percentage of strongly agrees, agrees, or somewhat agrees among secondary school students with 95% agreement.

Other notable findings include: students at all levels need more support in building their time management skills. The statement with the lowest agreement levels for elementary school students had to do with time management. Sixteen percent (16%) of elementary school students strongly disagreed, disagreed, or somewhat disagreed with the statement, “When I have a lot of homework, I can choose what needs to be done first.” The statement with the lowest agreement levels for secondary school students was “I am confident I can manage my time wisely when working on my own”, with 21% of students strongly disagreeing, disagreeing, or somewhat disagreeing with the statement.
Other statements with very high agreement among elementary school students were, “I try to help other children my age”, and “I am confident I can work well with students from different backgrounds” among secondary school students.

A few additional findings were that there was a small group of students who did not like STEM courses, who did not get enough time to work on STEM projects, and who felt that STEM education was not helpful.

**Summary:** Overall, students at all grade levels felt that they had developed the necessary STEM skills and competencies and that they enjoyed STEM education. Students at the elementary and secondary school levels showed very high agreement with the statements on STEM skills and competencies. Students of all grade levels believed that STEM education helped with engagement and helped them learn new information. Secondary school students felt that STEM education was relevant and meaningful to their life or future career. Elementary school students felt that STEM classes gave them the opportunity to build things, use technology, and work in groups. Students also felt strongly that the STEM skill they had developed the most was respect, and the area in which they need more development was time management.

**Students’ Sense of Belonging**

Secondary school students were asked about their sense of belonging in the classroom. The results demonstrated that a large proportion of students did not feel a sense of belonging in the classroom. Twenty-nine percent (29%) of secondary school students felt that they were not an important member of the classroom community (see Figure 39). This is an important result because it is fundamental that in our classrooms all students feel a sense of belonging to their learning community. Social structures in contemporary learning environments need to allow for diverse ideas and perspectives to promote creativity and innovation (Hondzel-Dishke, 2013). On top of that, districts need to focus on building positive relationships between administrators, educators and students by better understanding their emotions and relationships (Brooks, 2011).

**Summary:** Secondary school students were asked about their sense of belonging in the classroom. The results demonstrate that a large proportion of students did not feel a sense of belonging in the classroom. In fact, 29% of secondary school students felt that they were not an important member of the classroom community.
Figure 39: Secondary School Students Sense of Belonging

<table>
<thead>
<tr>
<th>Sense of belonging (Secondary)</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel like I am an important member of this classroom community.</td>
<td>9% (11)</td>
<td>8% (10)</td>
<td>13% (17)</td>
<td>34% (44)</td>
<td>22% (29)</td>
<td>14% (18)</td>
</tr>
</tbody>
</table>

Relevance of STEM

Secondary school students were asked whether STEM education was relevant and meaningful to their life or future career. Seventy-eight percent (78%) of students strongly agreed, agreed, or somewhat agreed with this statement. As such, most students felt that STEM education was relevant and meaningful to their life or future career (see Figure 40). This result is in line with current research on STEM education and educational initiatives. In recent years, STEM education has come to occupy a prominent place in the 21st century learning framework.

Figure 40: Relevance of STEM (Secondary School Students)

<table>
<thead>
<tr>
<th>Relevance of STEM (Secondary)</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I see STEM as personally meaningful and relevant to my life / my future career.</td>
<td>6% (8)</td>
<td>4% (5)</td>
<td>12% (16)</td>
<td>29% (37)</td>
<td>26% (34)</td>
<td>22% (29)</td>
</tr>
</tbody>
</table>

Summary: Most students felt that STEM education is relevant and meaningful to their life or future career, with 78% of students strongly agreeing, agreeing, or somewhat agreeing. This result is in line with current research on STEM education and educational initiatives. In recent years, STEM education has come to occupy a prominent place in the 21st century learning framework.

Feedback about STEM

Secondary school students were asked to indicate to what extent STEM education improved their learning (see Figure 41). A large percentage of students felt that STEM education improved their learning, but at the same time, almost 30% of students were not sure. The results were as follows: 66% of students said that STEM education improved their learning either to a great extent or to a moderate extent. Only 6% of students said that STEM education improved their learning to a minor extent or not at all, but 27% of students said they were not sure. There was no follow-up question for students who selected “not sure”, so it cannot be determined why students selected this response.
Figure 41: Feedback about STEM (Secondary School Students)

To what extent does Science, Technology, Engineering, and Math (STEM) education improve your learning?

<table>
<thead>
<tr>
<th>Response</th>
<th>Not really</th>
<th>To a minor extent</th>
<th>To a moderate extent</th>
<th>To a great extent</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1% (1)</td>
<td>6% (7)</td>
<td>28% (35)</td>
<td>38% (48)</td>
<td>27% (34)</td>
</tr>
</tbody>
</table>

Summary: Secondary school students were asked to what extent STEM education improved their learning. A large percentage of students felt that STEM education improved their learning, but almost 30% of students were not sure. There was no follow-up question for students who selected not sure, so it cannot be determined why students selected this response.

Students’ Interests in STEM Careers

Secondary school students were asked a series of questions about their interest in STEM careers. The goal was to better identify student career interests. The questions looked at students’ interests and career interests in the following areas: (1) arts, (2) mathematics, (3) science, (4) social science, (5) technology, (6) design, and (7) tools and machines (see Figure 42).

OVERALL Summary: Secondary school students were asked a series of questions about their interests in STEM careers and the mechanisms in the school to support them with their career choices. The results demonstrate that secondary school students were most interested in STEM careers, over other careers such as the arts or social sciences. In fact, the most popular career interests among secondary school students included: (1) careers that allowed them to create or design things, (2) technology, and (3) science.

Secondary school students were asked about mechanisms in the school to support them with their career choices. Based on the results, students felt that more could be done in the school to support them with their career choices. Students felt that teachers and guidance counsellors could have more discussions with them about potential career options and preparing for post-secondary education.

The results demonstrate that secondary students were most interested in STEM careers. In fact, the most popular career interests among secondary school students included: (1) careers that allowed them to create or design things (83% strongly agreed, agreed, or somewhat agreed), (2) technology (81% strongly agreed, agreed, or somewhat agreed), and (3) science (80% strongly agreed, agreed, or somewhat agreed). However, it is important to note that the lowest scoring STEM career was mathematics, with 68% of students strongly agreeing, agreeing, or somewhat agreeing.

To support these findings even further, students were asked about their affinity for STEM subjects. Overall, a high percentage of students (more than 78%) said they liked...
STEM subjects. Students strongly agreed, agreed, or somewhat agreed that they liked all of the STEM curricular areas (mathematics, science, and technology). The most liked curricular area was science, with 86% strongly agreeing, agreeing, or somewhat agreeing, followed by technology, with 84% strongly agreeing, agreeing, or somewhat agreeing.

On the other hand, the least popular curricular subject and career interest was the arts. Careers in the arts had the lowest agreement, with 50% of students strongly agreeing, agreeing, or somewhat agreeing, and in the same way student affinity for the arts had the lowest student agreement, with 74% of students strongly agreeing, agreeing, or somewhat agreeing.

This section on interest in STEM careers showed some statistically significant results between male and female students at the secondary school level, including the arts, mathematics, technology, and engineering.

Female students were more likely to strongly agree or agree that they liked the arts than male students (34% of females versus 22% males). Much in the same way, male students were more likely to strongly disagree or disagree that they were interested in careers in the arts than their female counterparts (23% of males versus 9% of females).

On the other hand, male students were more likely to strongly agree or agree that they liked math and were interested in careers that used math than female students in the study. The results were as follows: 34% of males strongly agreed or agreed that they liked math compared to 21% of females. Thirty-two percent (32%) of males strongly agreed or agreed that they were interested in careers that used math compared to 19% of females.

As well, male students were more likely to be interested in technology or careers that used technology than female students. Both of these results were statistically significant. Forty-six percent (46%) of males strongly agreed or agreed that they were interested in technology compared to 24% of female students. In the same way, 43% of male students strongly agreed or agreed that they were interested in careers that used technology, while only 19% of females strongly agreed or agreed.

While this was not a statistically significant result, 31% percent of male students strongly agreed or agreed that they would be interested in a career that would allow them to create or design things, in comparison to 21% of females. Additionally, male
students were more likely than female students to be interested in a career that would allow them to work with objects, machines, or tools (33% of male students strongly agreed or agreed that they would be interested in this type of career, while 13% of females strongly agreed or agreed).

Figure 42: Interest in STEM Careers (Secondary School Students)

<table>
<thead>
<tr>
<th>Interest in STEM Careers (Secondary)</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like the arts (e.g., drama, drawing, painting, writing).</td>
<td>8% (10)</td>
<td>5% (6)</td>
<td>13% (17)</td>
<td>20% (26)</td>
<td>22% (28)</td>
<td>33% (42)</td>
</tr>
<tr>
<td>I am interested in careers that use the arts.</td>
<td>16% (20)</td>
<td>18% (23)</td>
<td>17% (22)</td>
<td>27% (35)</td>
<td>7% (9)</td>
<td>16% (20)</td>
</tr>
<tr>
<td>I like math (e.g., work with numbers).</td>
<td>8% (10)</td>
<td>5% (7)</td>
<td>9% (11)</td>
<td>26% (33)</td>
<td>25% (32)</td>
<td>28% (36)</td>
</tr>
<tr>
<td>I am interested in careers that use math.</td>
<td>8% (10)</td>
<td>6% (8)</td>
<td>18% (22)</td>
<td>20% (25)</td>
<td>24% (30)</td>
<td>24% (30)</td>
</tr>
<tr>
<td>I like science (e.g., work with plants or animals; lab experiments; observe, learn, analyze, investigate, evaluate or solve problems; help people with their health).</td>
<td>3% (4)</td>
<td>5% (7)</td>
<td>5% (7)</td>
<td>24% (31)</td>
<td>29% (38)</td>
<td>33% (42)</td>
</tr>
<tr>
<td>I am interested in careers that use science.</td>
<td>5% (6)</td>
<td>7% (9)</td>
<td>9% (11)</td>
<td>20% (26)</td>
<td>27% (35)</td>
<td>32% (41)</td>
</tr>
<tr>
<td>I am interested in social sciences (e.g., geography, history).</td>
<td>11% (14)</td>
<td>15% (19)</td>
<td>16% (20)</td>
<td>29% (38)</td>
<td>16% (21)</td>
<td>13% (17)</td>
</tr>
<tr>
<td>I am interested in careers that use social sciences (e.g., help people, study and solve society’s problems; work in government).</td>
<td>15% (19)</td>
<td>14% (18)</td>
<td>17% (22)</td>
<td>30% (39)</td>
<td>12% (16)</td>
<td>12% (15)</td>
</tr>
<tr>
<td>I like to use technology for class work (e.g., work with computers, do research and analyze data, solve problems).</td>
<td>3% (4)</td>
<td>2% (3)</td>
<td>10% (13)</td>
<td>16% (21)</td>
<td>31% (40)</td>
<td>37% (48)</td>
</tr>
<tr>
<td>I am interested in careers that use technology.</td>
<td>5% (7)</td>
<td>8% (10)</td>
<td>5% (7)</td>
<td>22% (28)</td>
<td>22% (28)</td>
<td>38% (48)</td>
</tr>
<tr>
<td>I am interested in careers that allow me to create or design things.</td>
<td>3% (4)</td>
<td>6% (8)</td>
<td>8% (10)</td>
<td>33% (42)</td>
<td>22% (28)</td>
<td>28% (36)</td>
</tr>
<tr>
<td>I am interested in careers that allow me to work with objects, machines or tools.</td>
<td>9% (12)</td>
<td>8% (10)</td>
<td>13% (17)</td>
<td>27% (34)</td>
<td>28% (36)</td>
<td>15% (19)</td>
</tr>
<tr>
<td>Overall</td>
<td>8% (120)</td>
<td>8% (120)</td>
<td>12% (179)</td>
<td>25% (378)</td>
<td>22% (341)</td>
<td>26% (394)</td>
</tr>
</tbody>
</table>

Summary: Secondary school students were asked a series of questions about their interest in STEM careers. The results demonstrate that secondary school students were most interested in STEM careers. In fact, the most popular career interests among secondary school students included: (1) careers that allowed them to create or design things, (2) technology, and (3) science. The least popular STEM career was mathematics. The results also showed statistically significant results between male and female students in their STEM career interests. Male students were more likely to be interested in mathematics and careers that used math, compared to female students. On the other hand, female students were more likely to be interested in the arts and careers that used the arts than male students. Male students were also more likely than female students to be interested in careers that used technology, or that allowed them to work with objects, machines or tools.

Mechanisms in the School to Support Students with Career Choices
Secondary school students were asked about mechanisms in the school to support them with their career choices, post-secondary education choices, course selection, and deciding on future goals (see Figure 43). Based on the results, students felt that more could be done in the school to support them with their career choices. Thirty-eight
percent (38%) of students strongly disagreed, disagreed, or somewhat disagreed with the statement that “in my school, the teachers or the school guidance counsellor talk to me about possible jobs or careers that I can pursue,” and 36% of students strongly disagreed, disagreed, or somewhat disagreed with the statement that “in my school, the teachers or school guidance counsellor help me to choose the high school courses I need for post-secondary education.” Students did not fully agree that the teachers and guidance counsellors in their school supported them with their career choices and post-secondary education choices. For example, more students may be interested in careers in mathematics, the STEM career with the lowest student interest, if they were made more aware of possible career options.

**Figure 43: Mechanisms in Our School to Support Students with Career Choices**

<table>
<thead>
<tr>
<th>Mechanisms in our schools to support students with career choices, post-secondary education choices, course selection, deciding on future goals (Secondary)</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>In my school, the teachers or the school guidance counsellor talk to me about possible jobs or careers I can pursue.</td>
<td>15% (19)</td>
<td>14% (18)</td>
<td>12% (15)</td>
<td>33% (43)</td>
<td>19% (25)</td>
<td>9% (12)</td>
</tr>
<tr>
<td>In my school, the teachers or school guidance counsellor help me to choose the high school courses I need for post-secondary education.</td>
<td>11% (14)</td>
<td>11% (14)</td>
<td>14% (18)</td>
<td>26% (33)</td>
<td>27% (34)</td>
<td>12% (15)</td>
</tr>
<tr>
<td>Overall</td>
<td>13% (17)</td>
<td>12% (15)</td>
<td>12% (15)</td>
<td>30% (39)</td>
<td>23% (30)</td>
<td>11% (14)</td>
</tr>
</tbody>
</table>

**Summary:** Secondary school students were asked about the mechanisms in the school to support them with their career choices, post-secondary education choices, course selection, and deciding on future goals. Based on the results, students felt that more could be done in the school to support them with their career choices. Students felt that teachers and guidance counsellors could have more personal discussions with them about potential career options and prepare them for post-secondary education.

**EDUCATOR RESULTS**

School administrators and TDSB teachers from the 60 pilot STEM lead schools were asked a series of questions about Science, Technology, Engineering, and Mathematics (STEM) education. Overall, the goal was twofold: (1) to better understand educator perceptions and practices related to STEM education and (2) to identify the effectiveness of STEM-related Professional Learning activities. The questions were based on the work of Ravitz (2014), Ennis (2002), Zhu et al., (2013) and the Friday Institute for Educational Innovation (2012c).
Overall Study Demographics
Fifty (50) TDSB administrators and 80 teachers took part in the study. Each administrator and teacher completed a survey on their perceptions and practices of STEM education and the professional learning activities provided to them. The administrators and teachers worked in a wide range of grades and schools.

Role with the Board
Administrators and teachers were asked about their position with the board. Among the administrators, there was a mix of principals and vice-principals who completed the survey. Nonetheless, the overwhelming majority of administrator responses (82%) came from principals (see Figure 44).

Among teachers, both elementary and secondary school teachers were well-represented, however, the majority of the teachers who participated in the study were elementary school teachers. The breakdown was as follows: 58% of the teachers were elementary school teachers, 37% were secondary school teachers, and 5% selected “other” (see Figure 45).
Teaching Experience

Teachers were asked about their teaching experience including the grades they taught and their area of concentration. Most of the teachers taught a variety of grades and subject areas (see Figure 46).

Figure 46: Grade in Which You Teach

<table>
<thead>
<tr>
<th>Grade in which you teach: (Check all that apply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junior Kindergarten</td>
</tr>
<tr>
<td>Senior Junior Kindergarten</td>
</tr>
<tr>
<td>Grade 1</td>
</tr>
<tr>
<td>Grade 2</td>
</tr>
<tr>
<td>Grade 3</td>
</tr>
<tr>
<td>Grade 4</td>
</tr>
<tr>
<td>Grade 5</td>
</tr>
<tr>
<td>Grade 6</td>
</tr>
<tr>
<td>Grade 7</td>
</tr>
<tr>
<td>Grade 8</td>
</tr>
<tr>
<td>Grade 9</td>
</tr>
<tr>
<td>Grade 10</td>
</tr>
<tr>
<td>Grade 11</td>
</tr>
<tr>
<td>Grade 12</td>
</tr>
<tr>
<td>None of the above</td>
</tr>
</tbody>
</table>

All the grades from Junior Kindergarten to Grade 12 were represented in the study, however, the majority of teachers in the study taught in secondary school. In fact, the grades most represented were as follows: Grade 12 with 34% of teachers, Grade 11 with 33% of teachers, and Grade 9 with 27% of teachers. The grades with the least representation were JK-Grade 1 and Grade 6 which had less than 10% representation.

Figure 47: Concentration Area in Which You Teach

<table>
<thead>
<tr>
<th>Concentration area in which you teach:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom Teacher</td>
</tr>
<tr>
<td>Arts</td>
</tr>
<tr>
<td>Business Studies</td>
</tr>
<tr>
<td>Foreign Languages</td>
</tr>
<tr>
<td>Gifted/Enrichment</td>
</tr>
<tr>
<td>Guidance</td>
</tr>
<tr>
<td>Language Arts</td>
</tr>
<tr>
<td>Library or Media Services</td>
</tr>
<tr>
<td>Mathematics</td>
</tr>
<tr>
<td>Music</td>
</tr>
<tr>
<td>Physical Education/Health</td>
</tr>
<tr>
<td>Science</td>
</tr>
<tr>
<td>Social Science</td>
</tr>
<tr>
<td>Special Education</td>
</tr>
<tr>
<td>Technology</td>
</tr>
<tr>
<td>None of the above</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

The educators in this study taught in a wide range of subject areas including: Mathematics, Science, Language Arts, Social Science, Arts, Physical Education, and Technology. The most common teaching areas included: Mathematics (44%), Science (44%), Language Arts (30%), and Social Science (29%) (see Figure 47).
Perceptions of STEM Education

Teachers and administrators were asked about their perceptions of STEM education. Specifically, educators were asked about their: (1) perceptions of STEM education to improve student learning and (2) the viability and relevance of STEM education as a pedagogical approach.

OVERALL Summary: Teachers and administrators were asked about their perceptions of STEM education. Overwhelmingly, teachers and administrators would like the STEM strategy implementation to be continued. Ninety-eight percent (98%) of administrators and 82% of teachers said they would like to see the STEM strategy implementation continued.

Teachers and administrators felt strongly about the importance of STEM education to improve student learning. Teachers and administrators believed that STEM education could help with preparing students’ skills and competencies, enhancing student learning, solving real-world problems, and engaging in inquiry or problem-based learning. On the other hand, some administrators and teachers felt that the STEM transdisciplinary approach could diminish the individual importance of each content area. In addition to that, some teachers felt that STEM was a “fad”; however, administrators believed STEM education was an educational initiative here to stay.

Overall, teachers and administrators saw the value of STEM education and believed that it could improve student learning. Teachers and administrators believed that STEM education could help to prepare students with skills and competencies, enhance student learning, solve real-world problems, and engage in inquiry or problem-based learning.

Teachers and administrators were asked to state the words, phrases, or thoughts that came to mind when they thought of STEM education. For teachers and administrators, the top few words, phrases, or thoughts about STEM were: (1) inquiry-based learning, (2) problem-solving/problem-based learning, and (3) cross-curricular/interdisciplinary learning. There were differences between teachers and administrators in their immediate thoughts about STEM. Among teachers, the most popular word, phrase or thought that came to mind when thinking about STEM was the definition of Science, Technology, Engineering, and Mathematics. However, this perception was not shared with administrators. In fact, unlike teachers, some administrators viewed STEM in relation to entrepreneurship.

Teachers

Teachers felt very strongly that STEM education would help students to apply skills and solve problems that were relevant to the real world. Administrators felt very strongly...
that: (1) STEM education would prepare students with the skills and competencies needed for today’s and tomorrow’s world and (2) they saw the value of STEM integration to enhance student learning.

Additionally, teachers felt strongly about the importance of STEM education to improve student learning. Among all of the statements examining teacher perceptions of STEM to improve students’ learning, teachers had high levels of agreement with this statement. Teachers were asked five statements about STEM education and student learning, and about 80% of teachers strongly agreed or agreed with the statements. To add to this, less than 4% of teachers strongly disagreed or disagreed with the statements. The five statements about STEM education and student learning were as follows: (1) STEM education deepened students’ understanding of the world (79% strongly agreeing and agreeing), (2) STEM education helped students to apply skills and solve problems that were relevant to the real world (88% strongly agreeing and agreeing), (3) STEM education prepared students with the skills and competencies needed for today’s and tomorrows’ world (84% strongly agreeing and agreeing), (4) I see the value of STEM integrating to enhance student learning (81% strongly agreeing and agreeing), and (5) I understand the importance of STEM education in engaging students in inquiry-and problem-based learning (81% strongly agreeing and agreeing). Overall, teachers felt that STEM education helped to improve student learning.

On the other hand, teachers did not feel as strongly about the viability and relevance of STEM as a pedagogical approach. For example, the statement “I see STEM as another “fad” that will soon go away”, had 38% of teachers strongly agree, agree, or somewhat agree. To add to this, some teachers felt that the STEM transdisciplinary approach diminished the individual importance of each content area (19% strongly agree and agree) (see Figure 48).

**Administrators**

Administrators were also supportive and knowledgeable of STEM integration and perceptions of STEM education to improve student learning, but most administrators believed in the viability and relevance of STEM as a pedagogical approach.

For all the statements related to knowledge of STEM integration and perceptions of STEM teaching to improve student learning, there was near unanimous support. In fact, there were no administrators who strongly disagreed, disagreed, or somewhat disagreed with any of the statements. Nearly all of the administrators believed that STEM education can help prepare students with the skills and competencies they need.
They also agreed that it helped to enhance student learning, solve real-world problems, and engage students in inquiry- or problem-based learning. The results were as follows: 100% of administrators strongly agreed or agreed with the statements, “STEM education will prepare students with the skills and competencies needed for today’s and tomorrow’s world”, and “I see the value of STEM integration to enhance student learning.” This was followed by 98% of administrators who strongly agreed or agreed with the statement, “STEM education will help students to apply skills and solve problems that are relevant to the real world.”

In terms of viability and relevance of STEM education as a pedagogical approach, administrators see it as something that is here to stay; however, some administrators believe a problem of STEM education is that it can diminish the individual importance of each content area. Eighty-four percent (84%) of administrators strongly disagreed or disagreed with the statement, “I see STEM as another “fad” that will soon go away.” This demonstrates that administrators believe that STEM education is not a fad, but an important and long-term approach to education. On the other hand, some administrators feel that the STEM transdisciplinary approach can diminish the importance of individual content areas. In fact, 26% of administrators strongly agreed or agreed with the statement, “STEM transdisciplinary approach can diminish the importance of individual content areas” (see Figure 49).

**Figure 48: Perceptions of STEM Education (Teachers)**

<table>
<thead>
<tr>
<th>Please rate how much you agree or disagree with the following statements regarding your perceptions of STEM. (Teachers)</th>
<th>Somewhat Agree/Agree/Strongly Agree</th>
<th>Strongly Disagree/Disagree/Somewhat Disagree</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEM education will deepen students’ understanding of the world.</td>
<td>58% (42)</td>
<td>35% (25)</td>
<td>1% (1)</td>
</tr>
<tr>
<td>STEM education will help students to apply skills and solve problems that are relevant to the real world.</td>
<td>80% (58)</td>
<td>19% (14)</td>
<td>1% (1)</td>
</tr>
<tr>
<td>STEM education will prepare students with the skills and competencies needed for today’s and tomorrow’s world.</td>
<td>80% (58)</td>
<td>20% (14)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>I see the value of STEM integration to enhance student learning.</td>
<td>63% (45)</td>
<td>32% (23)</td>
<td>5% (3)</td>
</tr>
<tr>
<td>I understand the importance of STEM education in engaging students in inquiry and problem-based learning.</td>
<td>87% (63)</td>
<td>13% (9)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>I appreciate the need to plan and work closely with teachers in other disciplines to deliver STEM programming.</td>
<td>80% (58)</td>
<td>20% (14)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>STEM education will improve my teaching practice (e.g., increase content knowledge, integrate content from different disciplines).</td>
<td>70% (50)</td>
<td>30% (22)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>STEM transdisciplinary approach diminishes the individual importance of each content area.</td>
<td>69% (50)</td>
<td>31% (22)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>I see STEM as another “fad” that will soon go away.</td>
<td>60% (44)</td>
<td>39% (28)</td>
<td>1% (1)</td>
</tr>
<tr>
<td>Overall</td>
<td>63% (45)</td>
<td>37% (27)</td>
<td>0% (0)</td>
</tr>
</tbody>
</table>
Figure 49: Perceptions of STEM Education (Administrators)

<table>
<thead>
<tr>
<th>Please rate how much you agree or disagree with the following statements regarding your perceptions of STEM. (Administrators)</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEM education will deepen students’ understanding of the world.</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>10% (5)</td>
<td>44% (22)</td>
<td>46% (23)</td>
<td>5.36*</td>
</tr>
<tr>
<td>STEM education will help students to apply skills and solve problems that are relevant to the real world.</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>2% (1)</td>
<td>36% (18)</td>
<td>62% (31)</td>
<td>5.60*</td>
</tr>
<tr>
<td>STEM education will prepare students with the skills and competencies needed for today’s and tomorrow’s world.</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>35% (17)</td>
<td>65% (32)</td>
<td></td>
<td>5.65</td>
</tr>
<tr>
<td>I see the value of STEM integration to enhance student learning.</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>29% (14)</td>
<td>71% (35)</td>
<td></td>
<td>5.71</td>
</tr>
<tr>
<td>I understand the importance of STEM education in engaging students in inquiry or problem-based learning.</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>4% (2)</td>
<td>32% (16)</td>
<td>64% (32)</td>
<td>5.60</td>
</tr>
<tr>
<td>I appreciate the need to plan and work closely with teachers in other disciplines to deliver STEM programming.</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>4% (2)</td>
<td>32% (16)</td>
<td>64% (32)</td>
<td>5.60</td>
</tr>
<tr>
<td>STEM education will improve my teaching practice (e.g., increase content knowledge, integrate content from different disciplines).</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>12% (6)</td>
<td>31% (15)</td>
<td>57% (28)</td>
<td>5.45</td>
</tr>
<tr>
<td>STEM transdisciplinary approach diminishes the individual importance of each content area.</td>
<td>22% (11)</td>
<td>26% (13)</td>
<td>8% (4)</td>
<td>18% (9)</td>
<td>20% (10)</td>
<td>6% (3)</td>
<td>3.06</td>
</tr>
<tr>
<td>I see STEM as another “fad” that will soon go away.</td>
<td>40% (20)</td>
<td>44% (22)</td>
<td>10% (5)</td>
<td>2% (1)</td>
<td>4% (2)</td>
<td></td>
<td>1.92</td>
</tr>
<tr>
<td>Overall</td>
<td>7% (3)</td>
<td>8% (3)</td>
<td>2% (1)</td>
<td>6% (3)</td>
<td>29% (12)</td>
<td>49% (21)</td>
<td>4.47</td>
</tr>
</tbody>
</table>

* Significant Difference between Elementary and Secondary schools

Summary: Teachers and administrators were asked about their perceptions of STEM education. Teachers and administrators felt strongly about:

- The importance of STEM education to improve student learning.
- The value of STEM education to help prepare students’ skills and competencies, enhance student learning, solve real-world problems, and engage in inquiry- or problem-based learning.

Similarities between Teacher and Administrator Perceptions of STEM Education:

- STEM can help prepare students with the skills and competencies they need. It also helps to enhance student learning, solve real-world problems, and engage students in inquiry- or problem-based learning.
- STEM transdisciplinary approach can diminish the individual importance of each content area.

Differences between Teacher and Administrator Perception of STEM:

- Administrators believe that STEM education is an educational initiative here to stay; however, some teachers (38%) feel that it is a “fad.”

Wish to See the STEM Implementation Continued at School
Administrators and teachers were asked whether they would like to see the TDSB STEM strategy implementation continued at their school. Overwhelmingly, the answer was “Yes,” they would like it to be continued. Ninety-eight percent (98%) of administrators and 82% of teachers said they would like to see the TDSB STEM strategy implementation continued. To add to that, no administrators said “No” and only 4% of teachers said “No”, while the remainder said they were “Not Sure” (see Figures 50, 51, and 52). The primary aim of this study was to assess the implementation of the TDSB STEM strategy.
and based on this result, teachers and administrators demonstrated their strong support of the TDSB STEM strategy and would like it to continue.

**Figure 50: Wish to See the STEM Implementation Continued at School**

Teachers
- Yes: 82% (79)
- No: 4% (4)
- Not Sure: 14% (11)

Administrators
- Yes: 98% (50)
- No: 2% (1)
- Not Sure: 0%

**Figure 51: Wish to See TDSB STEM Strategy Implementation Continued at School (Teachers)**

Would you like to see the STEM implementation continued at your school?
- Yes: 82% (65)
- No: 4% (3)
- Not Sure: 14% (11)

**Figure 52: Wish to See TDSB STEM Strategy Implementation Continued at School (Administrators)**

Would you like to see the STEM implementation continued at your school?
- Yes: 98% (40)
- No: 0%
- Not Sure: 2% (1)

**Summary:** Administrators and teachers were asked whether they would like to see the STEM strategy implementation continued at their school. Overwhelmingly, the answer was “Yes”, they would like it to be continued. Ninety-eight percent (98%) of administrators and 82% of teachers said they would like to see the STEM strategy implementation continued. The primary aim of this study was to assess the implementation of the STEM strategy and based on this result, teachers and administrators demonstrated their strong support of the STEM strategy and would like it to continue.
RESULTS ON TEACHER KNOWLEDGE OF STEM EDUCATION

**Teacher Knowledge of STEM Education**

Teachers were asked about their knowledge of STEM education including knowledge of STEM careers, pedagogy, and resources.

**OVERALL Summary:** Teachers were asked about their knowledge of STEM careers, pedagogy and resources. The results were as follows:

**Knowledge of STEM careers:**
Currently, there are many teachers who feel they do not have a developed knowledge of STEM careers. Thirty-seven percent (37%) of teachers said they did not know where to go to learn more about STEM careers, and 23% of teachers felt they did not have a strong knowledge of current STEM careers.

**Knowledge of STEM pedagogy:**
Teachers feel that they have the necessary knowledge and understanding of STEM pedagogy and available resources.

**Strengths:**
Teachers feel that they have an understanding of the following STEM pedagogies: inquiry-based learning, problem-based learning and how to use various STEM-related technologies, and the importance of integration of different content areas when teaching. Teachers have created professional learning communities for STEM education.

**Areas for improvement:**
Some teachers feel their understanding of the Engineering design process is not fully developed.

**Knowledge of STEM education resources:**
Most teachers (90%) are aware of the use of various technologies for STEM education. Many teachers (59%) have not used the STEM education resources on the TDSB’s STEM K-12 Academic Workspace (AW) Site.

**STEM Competencies**

Teachers were asked about their STEM competencies, including their knowledge of STEM pedagogy and STEM education resources. Overall, teachers felt that they have the necessary knowledge and understanding of STEM pedagogy and know how to use the available resources. Specifically, teachers felt that they have an understanding of inquiry-based learning, problem-based learning and how to use various STEM-related technologies, and they understood the importance of integration of different content areas when teaching. However some teachers felt that their understanding of the
engineering design process was not fully developed. The results were as follows: (1) 96% of teachers strongly agreed, agreed, or somewhat agreed that they have an understanding of inquiry-based learning and how to use this strategy to help students develop the various STEM competencies, (2) 93% of teachers strongly agreed, agreed, or somewhat agreed that they have an understanding of problem-based learning and how to use this strategy to help students develop the various STEM competencies, (3) 90% of teachers strongly agreed, agreed, or somewhat agreed that they are aware of the use of various technologies for STEM education, and (4) 97% of teachers strongly agreed, agreed, or somewhat agreed that they understand the importance of integrating content from different subject areas and disciplines.

However, the results showed some teachers did not have a full understanding of the engineering design process and how to use this strategy to help students develop the various STEM competencies. In fact, 27% of teachers strongly disagreed, disagreed, or somewhat disagreed with the statement, “I have an understanding of the Engineering design process and how to use this strategy to help students develop the various STEM competencies.”

The results also showed that many teachers have not used the STEM education resources on the TDSB’s STEM K-12 Academic Workspace (AW) Site. In fact, 58% of teachers strongly disagreed, disagreed, or somewhat disagreed with the statement, “I have used the STEM education resources on the TDSB’s STEM K-12 Academic Workplace (AW) Site” (see Figure 53).

Figure 53: STEM Competencies

Please rate how much you agree or disagree with the following statements about STEM Competencies. (Teachers)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree 2</th>
<th>Somewhat Disagree 3</th>
<th>Somewhat Agree 4</th>
<th>Agree 5</th>
<th>Strongly Agree 6</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have an understanding of Inquiry-based learning and how to use this strategy to help students develop the various STEM competencies.</td>
<td>(0)</td>
<td>1% (1)</td>
<td>3% (2)</td>
<td>31% (22)</td>
<td>41% (29)</td>
<td>23% (16)</td>
<td>4.81</td>
</tr>
<tr>
<td>I have an understanding of Problem-based learning and how to use this strategy to help students develop the various STEM competencies.</td>
<td>(0)</td>
<td>3% (2)</td>
<td>4% (3)</td>
<td>24% (17)</td>
<td>49% (34)</td>
<td>20% (14)</td>
<td>4.79</td>
</tr>
<tr>
<td>I have an understanding of the Engineering design process and how to use this strategy to help students develop the various STEM competencies.</td>
<td>9% (6)</td>
<td>6% (4)</td>
<td>13% (9)</td>
<td>26% (18)</td>
<td>24% (17)</td>
<td>23% (16)</td>
<td>4.20</td>
</tr>
<tr>
<td>I have used STEM education resources on the TDSB STEM K-12 Academic Workspace (AW) site.</td>
<td>27% (19)</td>
<td>17% (12)</td>
<td>14% (10)</td>
<td>20% (14)</td>
<td>16% (11)</td>
<td>6% (4)</td>
<td>2.97*</td>
</tr>
<tr>
<td>I understand the importance of integrating content from different subjects areas and disciplines.</td>
<td>(0)</td>
<td>3% (2)</td>
<td>16% (11)</td>
<td>34% (24)</td>
<td>47% (33)</td>
<td>5.26</td>
<td></td>
</tr>
<tr>
<td>I am aware of the use of various technologies for STEM education.</td>
<td>(0)</td>
<td>1% (1)</td>
<td>9% (6)</td>
<td>29% (20)</td>
<td>43% (30)</td>
<td>17% (12)</td>
<td>4.67</td>
</tr>
<tr>
<td>Overall</td>
<td>6% (20)</td>
<td>5% (20)</td>
<td>8% (32)</td>
<td>24% (102)</td>
<td>35% (145)</td>
<td>23% (95)</td>
<td>4.45</td>
</tr>
</tbody>
</table>

* Significant Difference between Elementary and Secondary schools
Summary: Teachers were asked about their STEM competencies, including their knowledge of STEM pedagogy and STEM resources. Teachers felt that they have the necessary knowledge and understanding of STEM pedagogy and available resources. Specifically, teachers feel that they have an understanding of inquiry-based learning, problem-based learning and how to use various STEM related technologies, and they understood the importance of integration of different content areas when teaching. However, some teachers felt their understanding of the engineering design process was not fully developed. Also, the results showed that many teachers have not used the STEM education resources on the TDSB’s STEM K-12 Academic Workspace (AW) Site.

Professional Learning Community
Teachers were asked about their Professional Learning Community in regards to STEM education. The Ontario Ministry of Education believes in the importance of PLCs as a way to improve student achievement (Ontario Ministry of Education, The Literacy and Numeracy Secretariat, 2007). The government sees professional learning as a continuous way for educators to inform their practice in structured and meaningful ways (Ontario Ministry of Education, The Literacy and Numeracy Secretariat, 2007). They suggest that administrators and teachers: (1) reflect and learn together, (2) review student work and relevant data, (3) plan for student success, and (4) focus on students who are struggling (Ontario Ministry of Education, 2007).

The results from the study showed that teachers also believed in the importance of PLCs. They valued the importance of collaboration and co-planning of STEM activities, lessons, and initiatives. Eighty-nine percent (89%) of teachers strongly agreed, agreed, or somewhat agreed that they network and collaborate with colleagues regarding STEM education and 81% strongly agreed, agreed, or somewhat agreed that they co-plan and work with other colleagues around STEM teaching. Overall, TDSB teachers have created PLCs for STEM education (see Figure 54).

Figure 54: Professional Learning Communities

<table>
<thead>
<tr>
<th>Please rate how much you agree or disagree with the following statements about STEM Competencies (Teachers)</th>
<th>Strongly Disagree 1</th>
<th>Disagree 2</th>
<th>Somewhat Disagree 3</th>
<th>Somewhat Agree 4</th>
<th>Agree 5</th>
<th>Strongly Agree 6</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>I network and collaborate with colleagues regarding STEM</td>
<td>3% (2)</td>
<td>1% (1)</td>
<td>7% (5)</td>
<td>19% (13)</td>
<td>44% (31)</td>
<td>26% (18)</td>
<td>4.77</td>
</tr>
<tr>
<td>I co-plan and work with other colleagues around STEM</td>
<td>1% (1)</td>
<td>6% (4)</td>
<td>11% (8)</td>
<td>20% (14)</td>
<td>37% (26)</td>
<td>24% (17)</td>
<td>4.59</td>
</tr>
<tr>
<td>Overall</td>
<td>2% (3)</td>
<td>4% (5)</td>
<td>9% (13)</td>
<td>19% (27)</td>
<td>41% (57)</td>
<td>25% (30)</td>
<td>4.68</td>
</tr>
</tbody>
</table>

* Significant Difference between Elementary and Secondary schools

Please rate how much you agree or disagree with the following statements about STEM Competencies (Teachers)

<table>
<thead>
<tr>
<th>Strongly Disagree 1</th>
<th>Disagree 2</th>
<th>Somewhat Disagree 3</th>
<th>Somewhat Agree 4</th>
<th>Agree 5</th>
<th>Strongly Agree 6</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>89% (70)</td>
<td>8% (7)</td>
<td>1% (1)</td>
<td>7% (5)</td>
<td>19% (13)</td>
<td>44% (31)</td>
<td>26% (18)</td>
</tr>
<tr>
<td>81% (70)</td>
<td>8% (7)</td>
<td>1% (1)</td>
<td>7% (5)</td>
<td>19% (13)</td>
<td>44% (31)</td>
<td>26% (18)</td>
</tr>
<tr>
<td>85% (140)</td>
<td>8% (7)</td>
<td>1% (1)</td>
<td>7% (5)</td>
<td>19% (13)</td>
<td>44% (31)</td>
<td>26% (18)</td>
</tr>
</tbody>
</table>
Summary: The results showed that teachers believed in the importance of Professional Learning Communities (PLCs). They value the importance of collaboration and co-planning of STEM activities, lessons, and initiatives. In turn, TDSB teachers have created PLCs for STEM education. Eighty-nine percent (89%) of teachers strongly agreed, agreed, or somewhat agreed that they network and collaborate with colleagues regarding STEM education and 81% strongly agreed, agreed, or somewhat agreed that they co-plan and work with other colleagues around STEM teaching.

STEM Career Awareness

Teachers were asked about their STEM career awareness including their knowledge of current STEM careers and where to get information and resources on STEM careers. A large number of teachers felt that they had sufficient knowledge of STEM careers and information, however, a sizable group of teachers felt that their knowledge of STEM careers was somewhat lacking. Thirty-seven percent (37%) of teachers said they did not know where to go to learn more about STEM careers. To add to that, 23% of teachers felt they did not have a strong knowledge of current STEM careers (see Figure 55). It is important that teachers are knowledgeable about STEM careers, and currently, there are many teachers who feel they do not have this knowledge.

Summary: Teachers were asked about their STEM career awareness. It is important that teachers are knowledgeable about STEM careers, and currently there are many teachers who feel they do not have this knowledge. Thirty-seven percent (37%) of teachers said they did not know where to go to learn more about STEM careers, and 23% of teachers felt they did not have a strong knowledge of current STEM careers.

Figure 55: STEM Career Awareness

Please rate how much you agree or disagree with the following statements about STEM Career Awareness (Teachers).

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree 1</th>
<th>Disagree 2</th>
<th>Somewhat Disagree 1</th>
<th>Somewhat Disagree 2</th>
<th>Somewhat Agree 1</th>
<th>Agree 1</th>
<th>Strongly Agree 1</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>About current STEM careers.</td>
<td>1% (1)</td>
<td>3% (2)</td>
<td>9% (6)</td>
<td>27% (19)</td>
<td>30% (21)</td>
<td>21% (15)</td>
<td>11% (8)</td>
<td>11% (8)</td>
<td>4.27</td>
</tr>
<tr>
<td>Where to go learn more about STEM careers.</td>
<td>1% (1)</td>
<td>9% (6)</td>
<td>27% (19)</td>
<td>30% (21)</td>
<td>21% (15)</td>
<td>11% (8)</td>
<td>3.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Where to find resources for teaching students about STEM careers.</td>
<td>3% (2)</td>
<td>9% (6)</td>
<td>20% (14)</td>
<td>35% (24)</td>
<td>25% (17)</td>
<td>9% (6)</td>
<td>3.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Where to direct students or parents to find information about STEM careers.</td>
<td>6% (4)</td>
<td>9% (6)</td>
<td>20% (14)</td>
<td>39% (27)</td>
<td>17% (12)</td>
<td>10% (7)</td>
<td>3.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>3% (8)</td>
<td>7% (20)</td>
<td>22% (60)</td>
<td>34% (95)</td>
<td>24% (67)</td>
<td>10% (29)</td>
<td>4.01</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TEACHER RESULTS ON TEACHING EFFICACY AND BELIEFS

Teachers were asked about their self-efficacy in STEM education and their practices used to teach STEM.

OVERALL Summary: What is teachers’ sense of self-efficacy regarding STEM education?
Overall, teachers were confident in their ability to teach STEM effectively. Teachers feel that they are continually improving their STEM teaching practice; however, some teachers question whether they have the necessary skills to teach STEM.

OVERALL Summary: What practices do teachers use to teach STEM?
The most common practices used to teach STEM are: using technology to share information, taking initiative when confronted with a difficult question, and using technology to support teamwork and collaboration.
The least used practices to teach STEM are: having students choose their own topics of learning or questions to pursue, discussing issues related to global interdependency, and creating joint projects using contributions from each student.
OVERALL Summary: Following are the results in regards to teaching practice:

Current Teaching:
- Most teachers feel that they have tried to develop students’ STEM skills, and that the students have in turn learned the STEM skills.
- Some teachers feel that they find it difficult to effectively assess STEM skills.

Creativity and Innovation Skills:
- Teachers report that they regularly use a variety of teaching practices that support creativity and innovation such as having students generate their own ideas to a problem, invent a solution to a complex question, or create an original product to express their ideas.
- The most popular teaching strategy to develop creativity was having students generate their own ideas about how to confront a problem or question.
- The least often used strategy was having students create an original product or performance to express their ideas.

Self-direction:
- The results demonstrate that students are given a lot of opportunity to take initiative when confronted with a challenging problem and plan the appropriate steps needed to complete a complex task.
- Students are not given a lot of opportunities to choose their own topics of learning or questions to pursue. In fact, 50% of teachers reports that they never, rarely or sometimes have students choose their own topics of learning or questions to pursue.

Critical thinking:
- A moderate percentage of teachers (about 70%) report using a variety of teaching techniques regularly to help develop critical thinking. This includes having students draw their own conclusions based on analysis and trying to solve complex problems that have no single correct answer.

Collaboration Skills:
- The majority of teachers regularly use teaching practices that foster collaboration skills. Just over two thirds of teachers report that they have students work with others to set goals and have students collaborate to create joint products all the time or often.

Using technology as a tool for learning:
- Most teachers use technology as a tool for learning all the time, often or sometimes. Just over two thirds of teachers report that they regularly use technology as a tool for learning.

Global Connections:
- Global connections are not being fostered to the same degree as the other teaching practices/student skills.
- Thirty-one percent of teachers report that they never or rarely discuss issues related to global interdependency.

Guidance and Career support:
- A large percentage of teachers (79%) report that they often talk to students about possible careers or jobs they can pursue, however, fewer teachers report talking to students about the courses they need for post-secondary education (33% report that they do not this).
Confidence and Self-efficacy in STEM Subject Content and Teaching

Teachers were asked about their confidence and self-efficacy in STEM subject content and teaching. Self-efficacy refers to one’s belief in his or her capacity to execute behaviors necessary to produce specific goals. In this case, the study examined teachers’ own beliefs in their ability to successfully teach STEM education. Overall, teachers were confident in their ability to teach STEM effectively. This was reported by 84% of teachers.

Nearly all of the teachers felt that they were continually improving their STEM teaching practice. Ninety percent (90%) of teachers strongly agreed, agree, or somewhat agreed that they were continually improving their STEM teaching practice.

On the other hand, even though a high percentage of teachers said they are confident in their teaching of STEM, a significant percentage of teachers wondered if they have the necessary skills to teach STEM. In fact, 40% of teachers strongly agreed, agreed, or somewhat agreed that they wonder if they have the necessary skills to teach STEM (see Figure 56).

Overall, teachers felt: (1) confident in their ability to teach STEM, (2) that they are continually improving their STEM teaching practices, and (3) some teachers questioned whether they have the necessary skills to teach STEM.

Figure 56: Confidence and self-efficacy in STEM subject content and teaching

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am continually improving my STEM teaching practice.</td>
<td>1% (1)</td>
<td>1% (1)</td>
<td>7% (5)</td>
<td>16% (11)</td>
<td>47% (33)</td>
<td>27% (19)</td>
<td>4.87</td>
</tr>
<tr>
<td>I am confident that I can teach STEM effectively.</td>
<td>1% (1)</td>
<td>3% (2)</td>
<td>12% (8)</td>
<td>30% (21)</td>
<td>38% (26)</td>
<td>16% (11)</td>
<td>4.48</td>
</tr>
<tr>
<td>I wonder if I have the necessary skills to teach STEM.</td>
<td>16% (11)</td>
<td>28% (19)</td>
<td>16% (11)</td>
<td>29% (20)</td>
<td>9% (6)</td>
<td>1% (1)</td>
<td>2.91</td>
</tr>
<tr>
<td>Given a choice, I would invite a colleague to evaluate my STEM teaching.</td>
<td>6% (4)</td>
<td>14% (10)</td>
<td>19% (13)</td>
<td>20% (14)</td>
<td>33% (23)</td>
<td>7% (5)</td>
<td>3.83</td>
</tr>
<tr>
<td>I know what to do to increase student interest in STEM.</td>
<td>1% (1)</td>
<td>4% (3)</td>
<td>13% (9)</td>
<td>40% (28)</td>
<td>30% (21)</td>
<td>11% (8)</td>
<td>4.27</td>
</tr>
<tr>
<td>Overall</td>
<td>5% (18)</td>
<td>10% (35)</td>
<td>13% (46)</td>
<td>27% (94)</td>
<td>32% (109)</td>
<td>13% (44)</td>
<td>4.08</td>
</tr>
</tbody>
</table>

Summary: Teachers were asked about their confidence and self-efficacy in STEM subject content and teaching. Overall, teachers were confident in their ability to teach STEM effectively. Eighty-four percent (84%) of teachers were confident that they can teach STEM effectively. The results also show that teachers felt they are continually improving their STEM teaching practice; however, some teachers questioned whether they have the necessary skills to teach STEM.
Current Teaching Related to STEM: General
Teachers were asked about their current teaching related to STEM. Specifically, teachers were asked about the development and assessment of students’ STEM skills. Most teachers felt that they have tried to develop students’ STEM skills, and that the students have in turn learned the STEM skills. Even so, the teachers felt that effective assessment of STEM skills remained difficult. The results were as follows: 82% of teachers have tried to develop students’ STEM skills to a great or moderate extent, 77% of teachers felt that most students have learned STEM skills while in their class to a great or moderate extent, and 33% of teachers felt that they have not been able to effectively assess students’ STEM skills (see Figure 57).

Figure 57: Current teaching related to STEM

<table>
<thead>
<tr>
<th>To what extent do you agree with the following statements about your current teaching? (Teachers)</th>
<th>Not Really</th>
<th>To a Minor Extent</th>
<th>To a Moderate Extent</th>
<th>To a Great Extent</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have tried to develop students’ STEM skills.</td>
<td>3% (2)</td>
<td>16% (11)</td>
<td>53% (37)</td>
<td>29% (20)</td>
</tr>
<tr>
<td>Most students have learned STEM skills while in my class.</td>
<td>6% (4)</td>
<td>17% (12)</td>
<td>56% (39)</td>
<td>21% (15)</td>
</tr>
<tr>
<td>I have been able to effectively assess students’ STEM skills.</td>
<td>10% (7)</td>
<td>23% (16)</td>
<td>46% (32)</td>
<td>21% (15)</td>
</tr>
</tbody>
</table>

Teachers were also asked about the teaching practices they used to support STEM learning. The most common practices teachers used to teach STEM were using technology to share information, taking initiative when confronted with a difficult question, and using technology to support team work and collaboration.

The least used practices to teach STEM were having students choose their own topics of learning or questions to pursue, discussing issues related to global interdependency, and creating joint projects using contributions from each student (see Figure 58).
Creativity and Innovation Skills

Teachers were asked about teaching practices that develop students’ creativity and innovation skills. Teachers reported that they regularly used teaching practices that support creativity and innovation such as having students generate their own ideas to a problem, invent a solution to a complex question, or create an original product to express their ideas.

Of the different teaching strategies that support creativity and innovation, some were used more frequently than others. The most popular teaching strategy to develop creativity was to have students generate their own ideas about how to confront a problem or question. Seventy-seven percent (77%) of teachers reported that they had...
their students do this all the time or often. This was also the only teaching practice that had no teachers report that they did this never or rarely. Thus, 100% of teachers had students generate ideas all the time, often, or sometimes.

The next most popular strategy was to have students invent a solution to a complex problem. Sixty-three percent (63%) of teachers reported that their students were given the opportunity to invent a solution to a complex, open-ended question or problem all the time or often. In comparison, the least used strategy was having students create an original product or performance to express their ideas, with 41% of teachers reporting that they never, rarely, or sometimes used this strategy (see Figure 59).

Figure 59: Creativity and Innovation Skills

<table>
<thead>
<tr>
<th>ET: Creativity and Innovation Skills</th>
<th>Never or Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>All the Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generate their own ideas about how to confront a problem or question</td>
<td>(0)</td>
<td>23% (16)</td>
<td>49% (34)</td>
<td>29% (20)</td>
</tr>
<tr>
<td>Invent a solution to a complex, open-ended question or problem</td>
<td>3% (2)</td>
<td>34% (24)</td>
<td>44% (31)</td>
<td>19% (13)</td>
</tr>
<tr>
<td>Create an original product or performance to express their ideas</td>
<td>4% (3)</td>
<td>37% (26)</td>
<td>39% (27)</td>
<td>20% (14)</td>
</tr>
<tr>
<td>Overall</td>
<td>2% (5)</td>
<td>31% (66)</td>
<td>44% (92)</td>
<td>22% (47)</td>
</tr>
</tbody>
</table>

Summary: Teachers reported that they regularly used a variety teaching practices that support creativity and innovation such as having students generate their own ideas to a problem, invent a solution to a complex question, or create an original product to express their ideas. Of the different strategies, some were used more frequently than others. The most popular teaching strategy to develop creativity was to have students generate their own ideas about how to confront a problem or question. The least often used strategy was having students create an original product or performance to express their ideas, with 41% of teachers reporting that they never, rarely or sometimes used this strategy.

Self-direction
Teachers were asked about their teaching practices that allow students to be self-directed. The results demonstrate that students were given a lot of opportunity to take initiative when confronted with a challenging problem, plan the appropriate steps needed to complete a complex task, but were not given as much opportunity to choose their own topics of learning or questions to pursue.

Teachers reported that they regularly had students take initiative when confronted with a difficult question and had students plan the steps they would take to accomplish a complex task. The results were as follows: 77% of teachers had students take initiative when confronted with a difficult problem or question all the time or often, and 73% of
teachers had students plan the steps they would take to accomplish a complex task all the time or often.

However, the results demonstrate that students were not given much opportunity to choose their own topic of learning or questions to pursue. In fact, 50% of teachers reported that they never, rarely, or sometimes had students choose their own topics of learning or questions to pursue (see Figure 60).

Figure 60: Self-direction

<table>
<thead>
<tr>
<th>Self-direction</th>
<th>Never or Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>All the Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Take initiative when confronted with a difficult problem or question</td>
<td>3% (2)</td>
<td>20% (14)</td>
<td>50% (35)</td>
<td>27% (19)</td>
</tr>
<tr>
<td>Choose their own topics of learning or questions to pursue</td>
<td>9% (6)</td>
<td>41% (29)</td>
<td>39% (27)</td>
<td>11% (8)</td>
</tr>
<tr>
<td>Plan the steps they will take to accomplish a complex task</td>
<td>3% (2)</td>
<td>24% (17)</td>
<td>51% (36)</td>
<td>21% (15)</td>
</tr>
<tr>
<td>Overall</td>
<td>5% (10)</td>
<td>29% (60)</td>
<td>47% (98)</td>
<td>20% (42)</td>
</tr>
</tbody>
</table>

Summary: Teachers were asked about their teaching practices that allow students to be self-directed. The results demonstrated that students were given a lot of opportunity to take initiative when confronted with a challenging problem, plan the appropriate steps needed to complete a complex task, but were not given as much opportunity to choose their own topics of learning or questions to pursue. In fact, 50% of teachers reported that they never, rarely, or sometimes had students choose their own topics of learning or questions to pursue.

Critical Thinking

Teachers were asked about their teaching practices that develop and support students’ critical thinking. A moderate percentage of teachers (about 70%) reported using a variety of teaching techniques regularly to help develop critical thinking. Nonetheless, there were teaching practices, such as having students analyze competing arguments, perspectives or solutions to a problem, that were not used as regularly.

The most common teaching practice to develop critical thinking was having students draw their own conclusions based on analysis of numbers, facts or relevant information. Seventy-nine percent (79%) of teachers reported they had students do this all the time or often. The second most popular teaching practice was having students try to solve complex problems or answer questions that have no single correct solution or answer, with 66% of teachers reporting they had their students do it all the time or often.

On the other hand, the teaching practice that was used the least regularly and that had the highest percentage of teachers report that they never used it, was having students
analyze competing arguments, perspectives, or solutions to a problem. Thirty-nine percent (39%) of teachers reported that they never, rarely, or only sometimes had students analyze competing arguments, perspectives, or solutions to a problem (see Figure 61).

**Figure 61: Critical Thinking**

<table>
<thead>
<tr>
<th>Critical Thinking Skills</th>
<th>Never or Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>All the Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw their own conclusions based on analysis of numbers, facts or relevant information</td>
<td>3% (2)</td>
<td>19% (13)</td>
<td>56% (39)</td>
<td>23% (14)</td>
</tr>
<tr>
<td>Analyze competing arguments, perspectives or solutions to a problem</td>
<td>7% (5)</td>
<td>31% (22)</td>
<td>41% (29)</td>
<td>20% (14)</td>
</tr>
<tr>
<td>Try to solve complex problems or answer questions that have no single correct solution or answer</td>
<td>3% (2)</td>
<td>31% (22)</td>
<td>44% (31)</td>
<td>21% (15)</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>4% (9)</td>
<td>27% (57)</td>
<td>47% (99)</td>
<td>21% (45)</td>
</tr>
</tbody>
</table>

**Summary:** Teachers were asked about their teaching practices that develop students’ critical thinking. A moderate percentage of teachers (about 70%) reported using a variety of teaching techniques regularly to help develop critical thinking. This included having students draw their own conclusions based on analysis and trying to solve complex problems that have no single correct answer. However, the results showed the practice of having students analyze competing arguments, perspectives or solutions to a problem was not used as regularly as the other practices.

**Collaboration Skills**

Teachers were asked about how they fostered collaboration skills in their classrooms. Nearly over two thirds of teachers reported that they had students work with others to set goals and had students collaborate to create joint products. For both of the statements on collaboration, the results were quite similar. Seventy percent (70%) of teachers reported that they had students work with other students to set goals and create a plan for their team all the time or often, and 66% of teachers reported that they had students create joint products using contributions from each student all the time or often (see Figure 62).

**Figure 62: Collaboration Skills**

<table>
<thead>
<tr>
<th>Collaboration Skills</th>
<th>Never or Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>All the Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work with other students to set goals and create a plan for their team</td>
<td>6% (4)</td>
<td>24% (17)</td>
<td>50% (35)</td>
<td>20% (14)</td>
</tr>
<tr>
<td>Create joint products using contributions from each student</td>
<td>6% (4)</td>
<td>28% (19)</td>
<td>53% (36)</td>
<td>13% (9)</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>6% (8)</td>
<td>26% (36)</td>
<td>51% (71)</td>
<td>17% (23)</td>
</tr>
</tbody>
</table>
Summary: Teachers were asked about the collaboration skills they fostered in their classrooms. Overall, the majority of teachers used teaching practice that fostered collaboration skills regularly. Just over two thirds of teachers reported that they had students work with others to set goals and had students collaborate to create joint products all the time or often.

Using Technology as a Tool for Learning
Teachers were asked about their practices of using technology as a learning tool. Overall, most teachers (about 90%) used technology as a tool for learning, all the time, often, or sometimes. Approximately two thirds of teachers reported that they regularly used technology as a tool for learning. The results were as follows: 70% of teachers used technology to share information (e.g., multi-media presentations, presentation software, blogs, podcasts, etc.) all the time or often and 64% of teachers reported that they used technology to support team work or collaboration (e.g., shared work spaces, email exchanges, giving and receiving feedback, etc.) all the time or often (see Figure 63).

Summary: Most teachers (about 90%) used technology as a tool for learning, all the time, often, or sometimes. Just over two thirds of teachers reported that they regularly use technology as a tool for learning. The results were as follows: 70% of teachers used technology to share information all the time or often and 64% of teachers reported that they use technology to support team work or collaboration all the time or often.

Global Connections
Teachers were asked about their classroom practices that allow students to create global connections. Overall, the results demonstrated that global connections were not being fostered to the same degree as the other teaching practices/student skills. Thirty-one percent (31%) of teachers reported that they never or rarely discussed issues related to global interdependency. As well, 14% of teachers reported that they never or rarely have students reflect on how their own experiences and local issues were connected to global issues. In comparison to the other practices, global connections had the highest percentage of teachers never or rarely giving students opportunities to develop this skill. For the other practices, typically 3-9% of teachers reported that they
never or rarely fostered that skill in their classroom in comparison to 31% of teachers who never or rarely discussed issues related to global interdependency (see Figure 64).

**Summary:** Teachers were asked about their classroom practices that develop students’ global connections. The results demonstrated that global connections were not being fostered to the same degree as the other teaching practices/student skills. Thirty-one percent (31%) of teachers reported that they never or rarely discussed issues related to global interdependency. As well, 14% of teachers reported that they never or rarely had students reflect on how their own experiences and local issues were connected to global issues. In comparison to the other practices examined, global connections had the highest percentage of teachers who never or rarely gave students opportunities to develop this skill. Typically, 3-9% of teachers reported never or rarely giving students an opportunity to foster that skill, in comparison to 31% of teachers who reported discussing issues related to global interdependency.

**Guidance and Career Support**
Teachers were asked about the guidance and career support they provided to students. A large percentage of teachers reported that they often talked to students about possible careers or jobs they can pursue, however, only a small percentage of teachers talked to students about the courses they needed for post-secondary education. The results were as follows: 79% of teachers strongly agreed, agreed, or somewhat agreed that they talked with students about possible jobs or careers they can pursue. However, 33% of teachers reported that they strongly disagreed, disagreed, or somewhat disagreed that they talked to students about courses they needed for post-secondary education (see Figure 65).
**Summary:** Teachers were asked about the guidance and career support they provided to students. A large percentage of teachers (79%) reported that they often talked to students about possible careers or jobs they can pursue, however, fewer teachers reported talking to students about the courses they needed for post-secondary education (33% reported that they do not this).

**EDUCATOR RESULTS ON STEM PROGRAM IMPLEMENTATION**

Administrators and teachers were asked about STEM program implementation in their schools. They were specifically asked about the resources, professional learning, and support they received to deliver STEM programming.

**OVERALL SUMMARY:** The results of study show that the pilot schools received some of the necessary resources, professional learning, and support they needed to deliver impactful STEM programming, but that there was still more that could be done.

**Resources**
Pilot school administrators reported that while they received STEM resource kits, other resources including STEM monographs and interactive probeware and software technologies were not as widely received. Only 22% of schools received STEM monographs and 28% received interactive probeware and software technologies.
OVERALL SUMMARY: Professional Learning
Administrators and teachers felt that STEM Learning Coaches provided effective professional learning opportunities; however, they both felt there were some areas that could be improved upon such as providing career information, assisting with STEM start-ups and developing assessment criteria for STEM education.

All of the schools in the study were given an opportunity to work with STEM Learning Coaches during the 2014-15 school year. In most cases, STEM Learning Coaches worked with individual teachers or worked with the school's STEM implementation Professional Learning Team (PLT). Nearly all of the teachers in the study (91%) had an opportunity to work with STEM Learning Coaches.

A large majority of administrators and teachers were very pleased with the quality of support received from the STEM Learning Coaches. It is important to note, however, that there was a small percentage of administrators and teachers who were not as pleased with the support they received from the STEM Learning Coaches.

Administrators and teachers reported that STEM Learning Coaches provided support in the following ways:

- Providing STEM teaching and learning resources
- Supporting teachers in using the STEM resource kits and monographs
- Providing professional learning focused on hands-on learning experiences
- Co-planning with teachers and assisting with classroom lessons and programs.

However, there were a few areas in which administrators and teachers reported having little or no support. These areas included:

- Providing career information
- Assisting with STEM start-ups
- Developing success criteria and metrics to assess the effectiveness of the STEM program.

Teachers and administrators would like to see the following professional learning to support the implementation of the STEM strategy:

- Continued and consistent access to STEM Learning Coaches
- More time for planning and collaboration
- More resources (i.e., unit plans, technology, activities)
- Best practices/teaching strategies for STEM
- More professional development (indicated by teachers, and not administrators, this was one of the differences in results)
- Time to observe others teaching using STEM pedagogy (indicated by teachers, and not administrators, this was one of the differences in results)
- More partnerships, school to school and between schools and outside organizations, (indicated by administrators, and not teachers, this was one of the differences in results).
OVERALL SUMMARY: Support
Teachers and administrators were asked about the organizational support received in their school environments. Both teachers and administrators felt that the school nurtures a culture of trust and risk-taking, but both felt that teachers in the school did not really work as an innovative team. Notable differences among administrator and teacher results included: administrators felt that the school did not provide enough time for teachers to plan and implement STEM teaching activities, and teachers felt that the school provided necessary material for students to do STEM activities and projects.

STEM-related Activities
Teachers were asked about the STEM-related activities or projects they provided for their students during the 2014-15 school year. A variety of STEM-related activities were reported including robotics, experiments, building prototypes, field trips, and speakers (see Figure 66). The results of the study showed that teachers used a variety of STEM-related activities; however, some activities were more utilized than others. The most popular activities reported were: hands-on activities (90% of teachers), experiments (67% of teachers) and the use of computer technology for data collection, analysis and presentation (64% of teachers). On the other hand, the least used STEM-related activities were: co-op opportunities with business and community partners (3% of teachers), and site visits (14% of teachers). Students should be given opportunities to participate in as many different STEM-related activities as possible and it could be a goal to have more teachers try to use some of the under-utilized activities such as co-op opportunities, site visits, robotics, and speakers more often in their class. It is worth noting that 4% of teachers reported they did not use any of the STEM-related activities in their classes. It is important that all teachers try to provide students with STEM-related learning experiences.
Figure 66: STEM-related Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Career exploration in STEM-related fields</td>
<td>30% (21)</td>
</tr>
<tr>
<td>Co-op opportunities with business and community partners</td>
<td>3% (2)</td>
</tr>
<tr>
<td>Competitions</td>
<td>41% (29)</td>
</tr>
<tr>
<td>Experiments</td>
<td>67% (47)</td>
</tr>
<tr>
<td>Field trips</td>
<td>47% (33)</td>
</tr>
<tr>
<td>Hands-on activities</td>
<td>90% (63)</td>
</tr>
<tr>
<td>Mentorship</td>
<td>19% (13)</td>
</tr>
<tr>
<td>Robotics</td>
<td>23% (16)</td>
</tr>
<tr>
<td>Site visits</td>
<td>14% (10)</td>
</tr>
<tr>
<td>Speakers</td>
<td>31% (22)</td>
</tr>
<tr>
<td>Using computer technology for data collection, analysis and presentation</td>
<td>64% (45)</td>
</tr>
<tr>
<td>Using technology and engineering design for students to build prototypes of solutions</td>
<td>50% (35)</td>
</tr>
<tr>
<td>None of the above</td>
<td>4% (3)</td>
</tr>
<tr>
<td>Other</td>
<td>6% (4)</td>
</tr>
</tbody>
</table>

Note: Percentages do not add up to 100% as respondents were able to select more than one response.

Summary: The results of the study show that teachers use a variety of STEM-related activities, however, some activities are utilized more than others. The most popular activities were: hands-on activities (90% of teachers), experiments (67% of teachers) and the use of computer technology for data collection, analysis and presentation (64% of teachers). On the other hand, the least used STEM-related activities were: co-op opportunities with business and community partners (3% of teachers), and site visits (14% of teachers). Four percent (4%) of teachers reported that they did not use any of the STEM-related activities in their classes. It is important that teachers try to provide students with a variety STEM-related learning experiences.

STEM Resources

Administrators were asked about the STEM resources their schools received. The resources included: STEM resource kits, STEM monographs, and interactive probeware and software technologies. Administrators reported that while they all received STEM resource kits, other resources including STEM monographs and interactive probeware and software technologies were not as widely received. All of the schools (100%) received STEM resource kits, but only 22% of schools received STEM monographs and 28% received interactive probeware and software technologies. However, 12% of administrators reported that they received “other” resources. These included items such as LEGO WeDo, LEGO EV3, and Arduinos (see Figure 67).
Administrators Results

Administrators were asked a series of questions regarding the STEM Learning Coaches in their school. Specifically, they were asked about the following areas: (1) in what capacity the STEM Learning Coaches worked with their school, (2) the types of support their school received from the STEM Learning Coaches, (3) administrator perceptions of the effectiveness of the support provided by the STEM Learning Coaches, and (4) their impression of the quality of the support received from the STEM Learning Coaches. Overall, administrators thought that STEM Learning Coaches provided important and effective support to their school in many ways, and a large percentage of administrators were satisfied with the quality of professional and coaching support they received from STEM Learning Coaches.
Overall Summary: Administrators were asked about the professional learning and support they received. The results are as follows: all of the schools in the study were given an opportunity to work with STEM Learning Coaches during the 2014-15 school year. In most cases, STEM Learning Coaches worked with individual teachers or worked with the school’s STEM implementation Professional Learning Team (PLT).

A large majority of administrators were very pleased with the quality of support they received from the STEM Learning Coaches. In fact, nearly half of the administrators rated the support they received from coaches as excellent. It is important to note, however, that there was a small percentage of administrators who were not as pleased with the support they received from the STEM Learning Coaches. As such, 18% of administrators rated the support they received from coaches as fair or poor.

Administrators reported that while they all received STEM resource kits, other resources including STEM monographs and interactive probeware and software technologies were not as widely received. Only 22% of the schools received STEM monographs and 28% received interactive probeware and software technologies.

Administrators reported that STEM Learning Coaches provided support in the following ways:

- Providing STEM teaching and learning resources
- Setting goals to move along the STEM continuum
- Supporting teaching in using the STEM resource kits and monographs
- Providing professional learning focused on hands-on learning experiences
- Co-planning with teachers and assisting with classroom lessons and programs.

However, there were a few areas that administrators reported receiving little or no support. These areas included:

- Providing career information
- Assisting with STEM start-ups
- Developing success criteria and metrics to assess the effectiveness of the STEM program.

STEM Learning Coaches: Work within the School

All of the pilot schools in the study were given an opportunity to work with STEM Learning Coaches during the 2014-15 school year. In most cases, STEM Learning Coaches worked with individual teachers or worked with the school’s STEM implementation Professional Learning Team (PLT). Ninety-four percent (94%) of schools had STEM Learning Coaches who worked with individual teachers, followed by 50% of schools in which STEM Learning Coaches worked with the school’s PLT (see Figures 68 and 69).
**Figure 68: Opportunity to Work with STEM Learning Coaches**

<table>
<thead>
<tr>
<th>Has your school had an opportunity to work with STEM Learning Coaches and/or STEM Instructional Leaders in the 2014-15 school year?</th>
</tr>
</thead>
<tbody>
<tr>
<td>O YES</td>
</tr>
<tr>
<td>O No – Skip to Question 6</td>
</tr>
</tbody>
</table>

**Figure 69: Capacity in Which STEM Learning Coaches Work with Your School**

<table>
<thead>
<tr>
<th>In what capacity do the STEM Learning Coaches and/or STEM Instructional Leaders work with your school in 2014-15? (Check all that apply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>O They work with our school's STEM implementation Professional Learning Team (PLT)</td>
</tr>
<tr>
<td>O They work with a specific department</td>
</tr>
<tr>
<td>O They work with individual teachers</td>
</tr>
<tr>
<td>O Other</td>
</tr>
</tbody>
</table>

**Summary:** All of the pilot schools in the study were given an opportunity to work with STEM Learning Coaches during the 2014-15 school year. In most cases, STEM Learning Coaches worked with individual teachers or worked with the school’s STEM implementation Professional Learning Team (PLT).

**STEM Learning Coaches: Support**

STEM Learning Coaches provided various supports to schools, and administrators were asked to report the types of support their school received and how effective their school found the support.

Administrators felt that STEM Learning Coaches provided the most support in the following ways: (1) providing STEM teaching and learning resources (94% of administrators reported that they received this support), (2) setting goals to move along the STEM continuum (88% of administrators reported receiving this support), (3) supporting teaching in using the STEM resource kits and monographs (88% of administrators reported receiving this support). Other areas in which schools received high levels of support included professional learning focused on hands-on learning experiences, and co-planning with teachers and assisting with classroom lessons and programs. There were seven different areas in which more than 80% of administrators reported receiving support.

However, there were a few areas that administrators reported receiving little or no support. These areas included: (1) providing career information (43% of administrators reported that they did not receive this support), (2) assisting with STEM start-ups (47% of administrators reported that they did not receive this support), and (3) developing success criteria and metrics to assess the effectiveness of the STEM program (28% of administrators reported that they did not receive this support). The area with the lowest
The reported level of support was providing career information. Only 8% of administrators reported receiving this support (see Figure 70).

**Figure 70: STEM Learning Coaches: Support (Administrators)**

<table>
<thead>
<tr>
<th>What types of support have your school received from your STEM Learning Coaches and/or STEM Instructional Leaders, and how effective did your school find the support? (Administrators)</th>
<th>Types of Support</th>
<th>Yes</th>
<th>No</th>
<th>Not Sure</th>
<th>Not Effective</th>
<th>Somewhat Effective</th>
<th>Effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting goals to move along the STEM continuum</td>
<td>88% (30)</td>
<td>3% (1)</td>
<td>9% (3)</td>
<td>20% (7)</td>
<td>26% (9)</td>
<td>34% (12)</td>
<td>43% (15)</td>
</tr>
<tr>
<td>Providing career information</td>
<td>49% (19)</td>
<td>28% (11)</td>
<td>23% (9)</td>
<td>16% (6)</td>
<td>12% (4)</td>
<td>34% (12)</td>
<td>57% (21)</td>
</tr>
<tr>
<td>Providing professional learning focused on a variety of hands-on learning experiences</td>
<td>86% (30)</td>
<td>14% (5)</td>
<td>0% (0)</td>
<td>37% (13)</td>
<td>63% (22)</td>
<td>74% (26)</td>
<td>100% (40)</td>
</tr>
<tr>
<td>Supporting teachers in how to use various strategies - Inquiry-based learning, Problem-based learning, and the Engineering design process - to help students develop STEM competencies</td>
<td>85% (28)</td>
<td>15% (5)</td>
<td>2% (1)</td>
<td>36% (15)</td>
<td>62% (23)</td>
<td>62% (23)</td>
<td>100% (40)</td>
</tr>
<tr>
<td>Developing success criteria and metrics to assess the effectiveness of the STEM program</td>
<td>86% (30)</td>
<td>14% (5)</td>
<td>0% (0)</td>
<td>37% (13)</td>
<td>63% (22)</td>
<td>62% (23)</td>
<td>100% (40)</td>
</tr>
<tr>
<td>Providing STEM teaching and learning resources</td>
<td>94% (31)</td>
<td>3% (1)</td>
<td>3% (1)</td>
<td>2% (2)</td>
<td>43% (15)</td>
<td>55% (20)</td>
<td>71% (26)</td>
</tr>
<tr>
<td>Supporting teachers in using the STEM resource kits and monographs</td>
<td>88% (29)</td>
<td>3% (1)</td>
<td>9% (3)</td>
<td>7% (3)</td>
<td>45% (19)</td>
<td>48% (20)</td>
<td>54% (21)</td>
</tr>
<tr>
<td>Co-planning with teachers and assisting them with classroom lessons and programs</td>
<td>86% (30)</td>
<td>9% (3)</td>
<td>6% (2)</td>
<td>5% (2)</td>
<td>40% (17)</td>
<td>55% (22)</td>
<td>62% (23)</td>
</tr>
<tr>
<td>Assisting with professional development for teachers on various technologies</td>
<td>82% (28)</td>
<td>12% (4)</td>
<td>6% (2)</td>
<td>7% (3)</td>
<td>36% (15)</td>
<td>57% (22)</td>
<td>71% (26)</td>
</tr>
<tr>
<td>Providing career information</td>
<td>8% (3)</td>
<td>43% (16)</td>
<td>49% (18)</td>
<td>28% (10)</td>
<td>61% (22)</td>
<td>11% (4)</td>
<td>28% (10)</td>
</tr>
<tr>
<td>Assisting with STEM start-ups (e.g., clubs)</td>
<td>37% (14)</td>
<td>47% (18)</td>
<td>16% (6)</td>
<td>12% (4)</td>
<td>40% (15)</td>
<td>48% (19)</td>
<td>62% (24)</td>
</tr>
<tr>
<td>Participating in or running the STEM showcases</td>
<td>58% (20)</td>
<td>25% (10)</td>
<td>18% (7)</td>
<td>3% (1)</td>
<td>40% (15)</td>
<td>57% (22)</td>
<td>100% (40)</td>
</tr>
<tr>
<td>Providing assessment/evaluation strategies (e.g., assessment of process)</td>
<td>54% (19)</td>
<td>20% (7)</td>
<td>26% (9)</td>
<td>13% (4)</td>
<td>53% (19)</td>
<td>33% (12)</td>
<td>33% (12)</td>
</tr>
<tr>
<td>Other</td>
<td>100% (4)</td>
<td>0% (0)</td>
<td>0% (0)</td>
<td>0% (0)</td>
<td>100% (4)</td>
<td>100% (4)</td>
<td>100% (4)</td>
</tr>
</tbody>
</table>

**Summary:** Administrators reported that STEM Learning Coaches provided a variety of support to schools. STEM Learning Coaches provided high levels of support by: (1) providing STEM teaching and learning resources, (2) setting goals to move along the STEM continuum, (3) supporting teachers in using the STEM resource kits and monographs, (4) providing professional learning focused on hands-on learning experiences, and (5) co-planning with teachers and assisting with classroom lessons and programs. However, there were a few areas that administrators reported receiving little or no support. These areas included: (1) providing career information, (2) assisting with STEM start-ups, and (3) developing success criteria and metrics to assess the effectiveness of the STEM program.

**STEM Learning Coaches: Effectiveness**

Administrators were asked to rate the overall quality of the professional and coaching support they received from their STEM Learning Coaches. A large majority of administrators (81%) were pleased with the quality of support received from the STEM Learning Coaches. In fact, nearly half of the administrators (49%) rated the support from coaches as excellent and 22% rated it as very good. Nonetheless, there was a small percentage of administrators who were not as pleased with the support they received from the STEM Learning Coaches. Eighteen percent (18%) of administrators rated the coaches as fair or poor (see Figure 71).
Like administrators, teachers were asked about their experience with STEM Learning Coaches. Specifically, they were asked the following questions: (1) whether they had the opportunity to work with STEM Learning Coaches, (2) the types of support they received from the STEM Learning Coaches, (3) the impact of the professional and coaching support they received, and (4) their overall impression of the quality of the support received from the coaches. Overall, nearly all the teachers had an opportunity to work with STEM Learning Coaches and many teachers felt that the coaches provided important and effective support to them in many ways.

**Summary:** A large majority of administrators were pleased with the quality of support received from the STEM Learning Coaches. In fact, nearly half of the administrators rated the coaching support as excellent. Nonetheless, there was a small percentage of administrators who were not as pleased with the support they received from the STEM Learning Coaches. Eighteen percent (18%) of administrators rated the coaching support as fair or poor.
Overall Summary: Nearly all of the teachers in the study (91%) had an opportunity to work with STEM Learning Coaches. A large percentage of the teachers felt that the STEM Learning Coaches were effective. In fact, 63% of the teachers rated the quality of coaching support as excellent or very good.

Teachers received a variety of support from STEM Learning Coaches that in most cases they felt was effective. According to the survey, teachers received the MOST support in the following areas:

- Professional learning
- Teaching resources
- Teaching strategies.

On the other hand, teachers received the LEAST amount of support in the following areas:

- Providing career information
- Assisting with STEM start-ups
- Providing assessment/evaluation strategies
- Developing success criteria.

In addition to that, teachers felt that STEM Learning Coaches were most effective at providing STEM teaching and learning resources, participating in or running STEM showcases, and providing professional learning focused on hands-on learning experiences. On the other hand, teachers felt that STEM Learning Coaches were less effective in providing career information, assisting with STEM start-ups, and setting goals to move along the STEM continuum.

The results demonstrate a wide range of opinions regarding teachers’ perceptions of the impact of the coaching support they received. However 68% of teachers felt the coaching had a great or moderate impact on their understanding of STEM education. The results also varied with regards to teachers’ perceptions of the impact of STEM coaching on their capacity to implement STEM. Nonetheless, 62% of teachers perceived that the coaching had a great or moderate impact on their capacity to implement STEM.

Opportunity to Work with STEM Learning Coaches

Teachers were asked if they had the opportunity to work with STEM Learning Coaches and/or STEM Instructional Leaders during the 2014-25 school year. Ninety-one percent (91%) of teachers reported that they had the opportunity to work with STEM Learning Coaches (see Figure 72).
Figure 72: Opportunity to Work with STEM Learning Coaches

Summary: Nearly all of the teachers in the study (91%) had an opportunity to work with STEM Learning Coaches during the 2014-15 school year.

STEM Learning Coaches: Support Received

Teachers were asked about the support they received from their STEM Learning Coaches. Specifically, they were asked to indicate the types of support they received and how effective they felt that support was.

In terms of the types of support teachers received from STEM Learning Coaches, the most common support received included: (1) professional learning focused on a variety of hands-on learning experiences (76% of teachers received this type of support), (2) STEM teaching and learning resources (64% of teachers received this type of support), and (3) supporting teachers in using various teaching strategies (60% of teachers received this type of support).

On the other hand, teachers also indicated areas in which they received little or no support from STEM Learning Coaches. These areas included: (1) providing career information (18% of teachers received this type of support), (2) assistance with STEM start-ups (26% of teachers received this type of support), (3) providing assessment and evaluation strategies (33% of teachers received this type of support), and (4) developing success criteria and metrics to assess the effectiveness of the STEM program (33% of teachers received this type of support).

Teachers were also asked to rate the effectiveness of the support they received from the STEM Learning Coaches. Teachers felt the coaches were most effective at providing
support in the following areas: (1) providing STEM teaching and learning resources (64% of teachers felt that STEM Learning Coaches were effective), (2) participating in or running the STEM showcases (58% of teachers felt that STEM Learning Coaches were effective), and (3) providing professional learning focused on a variety of hands-on learning experiences (55% of teachers felt that STEM Learning Coaches were effective).

While teachers felt that the STEM Learning Coaches were effective in many areas, there were some areas in which the coaches were not seen to be effective. These were in terms of providing career information (36% of teachers felt that STEM Learning Coaches were not effective), assisting with STEM start-ups (29% of teachers felt that STEM Learning Coaches were not effective), and setting goals to move along the STEM continuum (15% of teachers felt that STEM Learning Coaches were not effective).

Overall, teachers received a variety of support from STEM Learning Coaches that in most cases they felt was effective. The results indicate that teachers received the most support when it came to professional learning, teaching resources, and teaching strategies. On the other hand, teachers said that STEM Learning Coaches provided the least amount of support in providing career information, assisting with STEM start-ups, providing assessment/evaluation strategies, and developing success criteria. In addition, teachers felt that STEM Learning Coaches were most effective at providing STEM teaching and learning resources, participating in or running STEM showcases, and providing professional learning focused on hands-on learning experiences. However, they felt that STEM Learning Coaches were less effective in providing career support, assisting with STEM start-ups, and setting goals to move along the STEM continuum (see Figure 73).
Impact of Professional and Coaching Support Received

Teachers were asked how the coaching support received affected their understanding of STEM and their capacity to implement STEM in the classroom. The results demonstrate a wide range of opinions regarding teachers’ perceptions of the impact of the coaching support they received.

In terms of the effect of coaching on teachers’ understanding of STEM, the results were as follows: 29% of teachers felt the coaching had a great impact, 39% of teachers felt the coaching had a moderate impact, 19% felt the coaching had a slight impact, and 13% of teachers felt the coaching had no impact. Overall, the results show a range in opinions; however, 68% of teachers felt the coaching had a great or moderate impact on their understanding of STEM.

Summary: Overall, teachers received a variety of support from STEM Learning Coaches that in most cases they felt was effective. The results indicate that teachers received the most support when it came to professional learning, teaching resources, and teaching strategies. They felt they received the least amount of support from coaches in providing career information, assisting with STEM start-ups, providing assessment/evaluation strategies, and developing success criteria. In addition, teachers felt that STEM Learning Coaches were most effective at providing STEM teaching and learning resources, participating in or running STEM showcases, and providing professional learning focused on hands-on learning experiences. However, they felt that STEM Learning Coaches were less effective in providing career support, assisting with STEM start-ups, and setting goals to move along the STEM continuum.
In terms of the impact of the coaching support on the teachers’ capacity to implement STEM, the results were quite similar to that of the impact on understanding of STEM. Once again, the results varied. The results ranged from a great deal of impact to no impact on their capacity to implement STEM. The results were as follows: 31% of teachers felt the coaching had a great impact, 31% of teachers felt the coaching had a moderate impact, 23% of teachers felt the coaching had a slight impact, and 16% of teachers felt the coaching had no impact on their capacity to implement STEM. Nonetheless, 62% of teachers reported that the coaching had a great or moderate impact on their capacity to implement STEM (see Figure 74).

**Figure 74: Impact of Professional and Coaching Support (Teachers)**

<table>
<thead>
<tr>
<th>What impact did the professional and coaching support have on the following? (Teachers)</th>
<th>No Impact</th>
<th>Slight Impact</th>
<th>Moderate Impact</th>
<th>Great Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your understanding of STEM</td>
<td>13% (8)</td>
<td>19% (12)</td>
<td>39% (24)</td>
<td>29% (18)</td>
</tr>
<tr>
<td>Your capacity to implement STEM</td>
<td>16% (10)</td>
<td>23% (14)</td>
<td>31% (19)</td>
<td>31% (19)</td>
</tr>
</tbody>
</table>

**Summary:** Teachers were asked about the impact of the professional and coaching support they received on their understanding of STEM and their capacity to implement STEM. The results demonstrate a wide range of opinions regarding teachers’ perceptions of the impact of the coaching support they received.

Overall, the results show a range in opinions; however, 68% of teachers felt the coaching had a great or moderate impact on their understanding of STEM. The results also varied with regards to teachers’ perceptions of the impact of the STEM coaching on their capacity to implement STEM. Nonetheless, 62% of teachers felt the coaching had a great or moderate impact on their capacity to implement STEM.

**Overall Quality of Professional and Coaching Support Received**

Teachers were asked to rate the overall quality of support received from STEM Learning Coaches. Overall, a large percentage of teachers felt the STEM Learning Coaches provided quality support. In fact, 63% of teachers rated the coaches as excellent or very good. The detailed results are as follows: 35% of teachers rated the coaches as excellent, 28% rated the coaches as very good, 14% rated the coaches as good, 13% rated the coaches as fair, and 10% rated the coaches as poor (see Figure 75).

**Figure 75: Overall Quality of Professional and Coaching Support Received (Teachers)**
**Summary:** Overall, a large percentage of teachers felt the STEM Learning Coaches were effective. In fact, 63% of teachers rated the coaches as excellent or very good.

**Professional Learning, Resources, and Organizational Support**
Teachers and administrators were asked about the professional learning, resources and organizational support received during the implementation of the TDSB STEM strategy. The results are presented in the following section.

**Professional Learning and Support Needs**
Teachers and administrators were asked an open-ended question about the types of professional learning support they would find helpful as the TDSB STEM strategy implementation continues. There were similarities and differences among teacher and administrator responses. Teachers and administrators would both like to have the following support: (1) continued and consistent access to STEM Learning Coaches, (2) more time for planning and collaboration including with STEM Learning Coaches, (3) more resources (i.e., examples of unit plans, activities, teachers’ guides and technology), and (4) best practices/teaching strategies for STEM.

There were some differences among teachers and administrators on what types of professional learning and support they would find helpful. For example, teachers felt that the most helpful type of professional learning would be more hands-on workshops on implementations strategies and classroom activities. Teachers also indicated that they would like time to observe others teaching in the STEM classroom. Administrators did not discuss these ideas. Administrators, on the other hand, reported that partnerships (school to school and between schools and outside organizations) would help support the implementation of STEM teaching. Some administrators commented that it was important to ensure that all coaches were enthusiastic and knowledgeable. Teachers did not discuss these issues.
Organizational Support

Teachers and administrators were asked about the organizational support in their school environments. Both teachers and administrators had similar perceptions. Both teachers and administrators felt that their school nurtured a culture of trust and risk-taking, but that teachers in the school did not really work as an innovative team. Notable differences among administrator and teacher responses include administrators’ perception that the school did not provide enough time for teachers to plan and implement STEM teaching activities, and teachers’ perception that the school needed to provide necessary materials for students to do STEM activities and projects.

Overall, most administrators felt that the organizational support in the school was very good. In all 10 categories, there were very few administrators (less than 14%) who disagreed or strongly disagreed with the statement in regards to organizational support. The area with the highest level of administrator agreement was that the school nurtures a culture of trust and risk-taking. Ninety-four percent (94%) of administrators strongly agreed, agreed, or somewhat agreed with the statement, “our school nurtures a culture of trust and risk-taking.” Other important results includes that 46% of administrators only somewhat agreed with the statement, “teachers in my school really work as an innovative team.” Also, the statement with the highest level of disagreement was “our school provides enough time for teachers to plan and implement STEM teaching activities,” with 28% of administrators strongly disagreeing, disagreeing, or somewhat disagreeing with the statement.

Summary: Following is a summary of the types of professional learning teachers and administrators would like to see to support the implementation of the STEM strategy:

- Continued and consistent access to STEM Learning Coaches
- More time for planning and collaboration
- More resources (i.e., unit plans, technology, activities)
- Best practices/teaching strategies for STEM.

Additionally, teachers specifically requested:
- More professional development (hands-on workshops on implementations strategies and classroom activities)
- Time to observe others teaching STEM.

Administrators specifically requested:
- More partnerships, school to school and between schools and outside organizations
- Ensure all coaches are enthusiastic and knowledgeable.

Summary: Following is a summary of the types of professional learning teachers and administrators would like to see to support the implementation of the STEM strategy:

- Continued and consistent access to STEM Learning Coaches
- More time for planning and collaboration
- More resources (i.e., unit plans, technology, activities)
- Best practices/ teaching strategies for STEM.
Teachers had similar results to administrators. The areas with the highest level of teacher agreement was that the school nurtures a culture of trust and risk-taking and the school provides necessary material for students to do STEM activities and projects. Seventy-two percent (72%) of teachers strongly agreed, agreed, or somewhat agreed with the statement, “our school nurtures a culture of trust and risk-taking.” Seventy-seven percent (77%) of teachers also strongly agreed, agreed, or somewhat agreed with the statement, “our school provides the necessary materials for students to do STEM activities and projects.” It is also important to note the statements that had the highest level of disagreement among teachers. The statements were as follows: “our school provides enough time for teachers to plan and implement STEM teaching activities” (48% of teachers strongly disagreed, disagreed, or somewhat disagreed with the statement) and “the teachers in my school really work as an innovative team”, (39% of teachers strongly disagreed, disagreed, or somewhat disagreed with the statement) (see Figures 76 and 77).

**Figure 76: Organizational Support Received in Your School (Administrators)**

<table>
<thead>
<tr>
<th>How would you rate each of the following as related to the organizational support you receive in your school environment? (Administrators)</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our school provides enough time for teachers to plan and implement STEM teaching activities.</td>
<td>2% (1)</td>
<td>12% (6)</td>
<td>14% (7)</td>
<td>22% (11)</td>
<td>30% (15)</td>
<td>20% (10)</td>
<td>4.26</td>
</tr>
<tr>
<td>Our school provides the necessary materials for students to do STEM activities and projects.</td>
<td>(0)</td>
<td>4% (2)</td>
<td>8% (4)</td>
<td>28% (14)</td>
<td>40% (20)</td>
<td>20% (10)</td>
<td>4.64</td>
</tr>
<tr>
<td>Our school provides the necessary technology resources for STEM.</td>
<td>(0)</td>
<td>4% (2)</td>
<td>6% (3)</td>
<td>37% (18)</td>
<td>33% (16)</td>
<td>20% (10)</td>
<td>4.59</td>
</tr>
<tr>
<td>Most teachers in our school are open to changes in teaching.</td>
<td>4% (2)</td>
<td>4% (2)</td>
<td>14% (7)</td>
<td>36% (18)</td>
<td>38% (19)</td>
<td>4% (2)</td>
<td>4.12</td>
</tr>
<tr>
<td>The teachers in my school really work as an innovative team.</td>
<td>2% (1)</td>
<td>4% (2)</td>
<td>14% (7)</td>
<td>46% (23)</td>
<td>22% (11)</td>
<td>12% (6)</td>
<td>4.18</td>
</tr>
<tr>
<td>Our school creates opportunities for partnerships beyond school (e.g., involvement with business, sports, and arts communities).</td>
<td>4% (2)</td>
<td>6% (3)</td>
<td>10% (5)</td>
<td>29% (14)</td>
<td>35% (17)</td>
<td>16% (8)</td>
<td>4.33*</td>
</tr>
<tr>
<td>Our school provides high quality professional learning needed to foster STEM teaching and learning in my school.</td>
<td>2% (1)</td>
<td>4% (2)</td>
<td>14% (7)</td>
<td>36% (18)</td>
<td>34% (17)</td>
<td>16% (8)</td>
<td>4.38</td>
</tr>
<tr>
<td>Our school/district leaders are willing to listen attentively to teachers’ thoughts.</td>
<td>2% (1)</td>
<td>4% (2)</td>
<td>10% (5)</td>
<td>27% (13)</td>
<td>41% (20)</td>
<td>16% (8)</td>
<td>4.49</td>
</tr>
<tr>
<td>Our school shares collective goals and values regarding how the STEM program can help boost student achievement.</td>
<td>(0)</td>
<td>6% (3)</td>
<td>6% (3)</td>
<td>47% (23)</td>
<td>33% (16)</td>
<td>8% (4)</td>
<td>4.31</td>
</tr>
<tr>
<td>Our school nurtures a culture of trust and risk-taking.</td>
<td>(0)</td>
<td>0% (0)</td>
<td>6% (3)</td>
<td>20% (10)</td>
<td>48% (24)</td>
<td>26% (13)</td>
<td>4.94</td>
</tr>
<tr>
<td>Overall</td>
<td>2% (8)</td>
<td>5% (24)</td>
<td>10% (51)</td>
<td>32% (159)</td>
<td>35% (175)</td>
<td>16% (79)</td>
<td>4.42</td>
</tr>
</tbody>
</table>

* Significant Difference between Elementary and Secondary schools
Figure 77: Organizational Support Received in Your School (Teachers)

<table>
<thead>
<tr>
<th>How would you rate each of the following as related to the organizational support you receive in your school environment? (Teachers)</th>
<th>Strongly Disagree 1</th>
<th>Disagree 2</th>
<th>Somewhat Disagree 3</th>
<th>Somewhat Agree 4</th>
<th>Agree 5</th>
<th>Strongly Agree 6</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our school provides enough time for teachers to plan and implement STEM teaching activities.</td>
<td>10% (8)</td>
<td>16% (13)</td>
<td>22% (17)</td>
<td>25% (20)</td>
<td>22% (17)</td>
<td>5% (4)</td>
<td>3.47*</td>
</tr>
<tr>
<td>Our school provides the necessary materials for students to do STEM activities and projects.</td>
<td>6% (5)</td>
<td>6% (5)</td>
<td>10% (8)</td>
<td>32% (25)</td>
<td>32% (25)</td>
<td>13% (10)</td>
<td>4.15</td>
</tr>
<tr>
<td>Our school provides the necessary technology resources for STEM.</td>
<td>10% (8)</td>
<td>6% (5)</td>
<td>14% (11)</td>
<td>35% (28)</td>
<td>27% (21)</td>
<td>8% (6)</td>
<td>3.85</td>
</tr>
<tr>
<td>Most teachers in our school are open to changes in teaching.</td>
<td>4% (3)</td>
<td>16% (12)</td>
<td>22% (17)</td>
<td>34% (26)</td>
<td>19% (15)</td>
<td>5% (4)</td>
<td>3.65*</td>
</tr>
<tr>
<td>The teachers in my school really work as an innovative team.</td>
<td>10% (8)</td>
<td>15% (12)</td>
<td>14% (11)</td>
<td>37% (29)</td>
<td>16% (13)</td>
<td>8% (6)</td>
<td>3.57</td>
</tr>
<tr>
<td>Our school creates opportunities for partnerships beyond school (e.g., involvement with business, sports, and arts communities).</td>
<td>12% (9)</td>
<td>10% (8)</td>
<td>14% (11)</td>
<td>41% (32)</td>
<td>18% (14)</td>
<td>5% (4)</td>
<td>3.59</td>
</tr>
<tr>
<td>Our school provides high quality professional learning needed to foster STEM teaching and learning in my school.</td>
<td>9% (7)</td>
<td>10% (8)</td>
<td>16% (13)</td>
<td>39% (31)</td>
<td>18% (14)</td>
<td>8% (6)</td>
<td>3.70</td>
</tr>
<tr>
<td>Our school/district leaders are willing to listen attentively to teachers’ thoughts.</td>
<td>7% (5)</td>
<td>8% (6)</td>
<td>14% (11)</td>
<td>34% (26)</td>
<td>26% (20)</td>
<td>11% (8)</td>
<td>3.97</td>
</tr>
<tr>
<td>Our school shares collective goals and values regarding how the STEM program can help boost student achievement.</td>
<td>9% (7)</td>
<td>10% (8)</td>
<td>10% (8)</td>
<td>38% (29)</td>
<td>23% (18)</td>
<td>9% (7)</td>
<td>3.83*</td>
</tr>
<tr>
<td>Our school nurtures a culture of trust and risk-taking.</td>
<td>9% (7)</td>
<td>3% (2)</td>
<td>17% (13)</td>
<td>27% (21)</td>
<td>31% (24)</td>
<td>14% (11)</td>
<td>4.10</td>
</tr>
<tr>
<td>Overall</td>
<td>9% (67)</td>
<td>10% (79)</td>
<td>15% (120)</td>
<td>34% (267)</td>
<td>23% (181)</td>
<td>8% (66)</td>
<td>3.79</td>
</tr>
</tbody>
</table>

* Significant Difference between Elementary and Secondary schools

Summary: Teachers and administrators were asked about the organizational support received in their school environments. Both teachers and administrators felt that the school nurtures a culture of trust and risk-taking, but both felt that teachers in the school did not really work as an innovative team. Interestingly, administrators felt that the school did not provide enough time for teachers to plan and implement STEM teaching activities.

EDUCATOR RESULTS ON STAGE OF IMPLEMENTATION

Administrators and teachers were asked questions regarding the implementation of the TDSB STEM strategy, including the stage of implementation, challenges and barriers to implementations, and recommendation for the future.
OVERALL SUMMARY: Most of the pilot schools (76%) were at the Partial Implementation stage. The Partial Implementation stage refers to the fact that STEM methodology is being implemented in training, but not all teachers are implementing it in their classes. The remaining schools were at the Full Implementation stage (16%) or Preparation stage (8%) (Gjøvik, 2013).

Implementation Processes
Most of the schools have implemented the STEM Strategy through: (1) support from a STEM Learning Coach, (2) professional development, (3) interdepartmental learning and teaching, and (4) upgrades to technology.

Challenges to Implementation
Administrators and teachers were asked about the greatest challenges they experienced in implementing the STEM strategy. The challenges included:

- Not having enough time allocated (i.e., release time for planning, classroom time)
- Not having enough time with STEM Learning Coaches
- Lack of resources (e.g., more financial support was needed to buy resources and purchase supplies)
- Not having enough professional development (e.g., more STEM Learning Coaches needed, PD sessions)
- Lack of teacher confidence/understanding of STEM teaching and learning
- Resistance to change
- Unclear directions on how to cover the curriculum and include STEM activities.

Barriers to Implementation
Teachers and administrators were asked about the barriers to implementing the STEM strategy. Administrators felt that the largest problem was a lack of needed resources, followed by a lack of teacher content knowledge of STEM. Teachers, on the other hand, felt that the largest problem was a limited availability of professional learning opportunities.
OVERALL SUMMARY: Feedback on Coaching Model

Most administrators and teachers felt that the STEM Learning Coach model was an effective approach for professional learning. Eighty percent (80%) of administrators and 73% of teachers reported that they felt the STEM Learning Coach model was a very effective or moderately effective model. On the other hand, 20% of administrators and 26% of teachers rated the STEM Learning Coach model as not at all effective or only slightly effective.

Teachers and administrators who rated the STEM Learning Coach model as slightly effective or not at all effective were asked what other models of coaching they would suggest. Their suggestions were as follows:

- Hire more STEM Learning Coaches
- STEM Learning Coaches need to be on site more consistently and more often
- STEM Learning Coaches should be part of the staff
- More experienced STEM Learning Coaches with greater depth of knowledge should be selected
- Administrators recommended allowing principals to be the leader of the STEM program in the school.

Types of School Leadership Needed for Successful Implementation

Administrators were asked about the types of school leadership needed to enable the successful implementation of the TDSB STEM strategy. The most common responses were as follows:

- Provide support (e.g., access to resources, provide time for planning innovative programming)
- Be a leader (e.g., forward thinking, growth mindset, encouraging)
- Risk-Taker (e.g., openness to change, thinking outside the box, willingness to think about alternatives)
- Provide professional development (e.g., STEM Learning Coaches,
OVERALL SUMMARY: Recommendations Moving Forward

Teachers and administrators were asked to provide their recommendations for moving forward with the implementation of the STEM strategy. Both teachers and administrators believed that there was a need for additional funding for more resources, such as coaches, lessons plans, new technology, and classroom laptops. Another important recommendation made by both teachers and administrators was to allow more time for the STEM strategy to develop and give it our continued support.

Other Recommendations were as Follows:

- Administrators felt there needed to be improved coordination of such matters as timetables and release time, and that they would like to see professional learning for administrators on STEM.
- Administrators recommended continuing with STEM Learning Coaches with possibly a few changes such as:
  - Having more STEM Learning Coaches
  - STEM Learning Coaches need to be on site more often or be part of the staff
  - STEM Learning Coaches need to have more consistent and specified daily/weekly hours
  - Hiring STEM Learning Coaches with greater depth of knowledge.
- Teachers recommended integrating STEM education with the arts, having more professional learning, and having a designated classroom for STEM.

Overall Recommendations:

While teachers and administrators perceived the STEM initiative to be a good program overall, they had suggestions to make it more effective. Comments regarding STEM Learning Coaches include:

- STEM Learning Coaches should be present at departmental head meetings, staff meetings, inter-departmental meetings, etc.
- STEM Learning Coaches are assigned too many schools. Each coach should have fewer schools and devote more time to each school.
- Not all coaches are equally effective.
- Less confident teachers should be placed with coaches, rather than confident risk-taking teachers.

Other Comments:

- More funding is needed for resources
- STEM should be school-wide
- Continue collaboration with other schools
- Recognize the role that the arts play in STEM.
### Stages of Implementation of TDSB STEM Strategy

Using Gjøvik’s (2013) four levels of STEM implementation - “No Implementation,” “Preparation,” “Partial Implementation,” and “Full Implementation,” administrators were asked what level of STEM education was currently going on at their school. At the time of the survey, most of the pilot schools were at the Partial Implementation stage. At this stage, STEM methodology is being implemented with training, but not all teachers are implementing it, and people in the school are learning how to support STEM methods (Gjøvik, 2013). Seventy-six (76%) percent of STEM pilot schools were at the Partial Implementation stage at the time of the survey.

The remaining schools were at the Full Implementation or Preparation stage at the time of the survey (Gjøvik, 2013). It is important to note that no schools were in the No Implementation group. Sixteen percent (16%) of schools were at the Full Implementation stage which means that STEM is infused in the curriculum throughout the school and is supported by administration. Knowledge gained in STEM delivery is being evaluated and used to sustain persistent and skillful support of teachers and staff who are using STEM innovation effectively (Gjøvik, 2013). This was followed by 8% of schools who were on the other side of the spectrum, the Preparation stage. The Preparation stage means that the school is in the process of training teachers in STEM methodology, developing stakeholder relationship, and or/ identifying and procuring needed resources for implementation (Gjøvik, 2013) (see Figure 78).

#### Figure 78: Stages of Implementation

<table>
<thead>
<tr>
<th>What level of STEM education is currently occurring in your school? (This question is required)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>O No Implementation: No development of STEM methodology is taking place in our school at this time.</td>
<td>(0)</td>
</tr>
<tr>
<td>O Preparation: Our school is in the process of: training teachers in STEM methodology, developing stakeholder relationships; and/or identifying and procuring needed resources for implementation.</td>
<td>8% (4)</td>
</tr>
<tr>
<td>O Partial Implementation: We have implemented STEM methodology with training: not all teachers are implementing, but others in my school are learning how to support STEM methods.</td>
<td>76% (38)</td>
</tr>
<tr>
<td>O Full Implementation: STEM is infused in the curriculum throughout our school and is supported by administration. Knowledge gained in STEM delivery is being evaluated and used to sustain persistent and skillful support of teachers and staff who are using STEM innovation effectively.</td>
<td>16% (8)</td>
</tr>
</tbody>
</table>
Process and Strategies to Implement STEM Programming

Administrators were asked an open-ended question about the types of activities and processes their school had put into place to implement the TDSB STEM strategy. The most common responses were: (1) STEM Learning Coach, (2) professional learning, (3) inter-departmental learning and teaching, and (4) upgrades to technology. Other responses included: STEM fairs, STEM lunch ‘n learns, STEM partnerships (i.e., MaRS E-thinking project), and computer programming.

Challenges Schools Experienced in Implementing the TDSB STEM Strategy

Administrators and teachers were asked about the greatest challenges they experienced in implementing the TDSB STEM strategy. Time was cited as the greatest challenge for both teachers and administrators. This included timetable constraints, the lack of release time, and not enough classroom time for STEM activities. Other challenges that both teachers and administrators highlighted were: (1) lack of resources (e.g., more financial support was needed to buy resources and purchase supplies), (2) limited professional development opportunities (STEM Learning Coaches, PL Sessions), (3) lack of teacher confidence/understanding of STEM teaching and learning, (4) resistance to change, and (5) unclear directions on how to cover the curriculum and include STEM activities. In terms of challenges, there were no major differences reported between administrators and teachers as the two groups described similar challenges.

Other challenges mentioned by teachers included a lack of understanding of the TDSB STEM strategy, limited knowledge of how to use materials, and lack of a central database of STEM activities. For example, teachers commented that with the arrival of the STEM kits, teachers were not always clear about how to use the materials. Furthermore, one teacher commented that “There seemed to be a lack of
understanding amongst colleagues about the STEM initiative.” Another recommendation was to create a central database for teachers: “There needs to be a central database with complete STEM projects that teachers can “adapt and use, and can be searched under topics of subjects.”

**Summary:** Administrators and teachers were asked about the greatest challenges they experienced in implementing the STEM strategy. Teachers and administrators noted similar challenges. Following is a summary of the greatest challenges reported by teachers and administrators.

Summary of Greatest Challenges:
- More time is needed (i.e., release time for planning, classroom time)
- Not enough time with STEM Learning Coaches
- Lack of resources (e.g., more financial support was needed to buy resources and purchase supplies, more STEM Learning Coaches were needed)
- Not enough professional development (e.g., more STEM Learning Coaches were needed, PD sessions)
- Lack of teacher confidence/understanding of STEM teaching and learning
- Resistance to change
- Unclear directions on how to cover the curriculum and include STEM activities.

**Barriers to STEM Implementation**
Teachers and administrators were asked a series of questions regarding the barriers to implementation of the TDSB STEM strategy. According to administrators, the largest barrier was a lack of needed resources, followed by a lack of teacher content knowledge of STEM. For teachers, the largest barrier was the limited availability of professional learning opportunities. They also felt very strongly that leadership and support from the school principal, non-supportive teachers, and the culture of the school were not issues that hindered the TDSB STEM strategy implementation.

Administrators felt that the largest barrier was a lack of much needed resources (e.g., funding, equipment, supplies, etc.). In fact, 71% of administrators strongly agreed, agreed, or somewhat agreed that a lack of resources was a problem that hindered the STEM implementation. This was followed by 66% of administrators reporting a lack of teacher content knowledge. Additionally, 66% of teachers strongly disagreed, disagreed, or somewhat disagreed that the culture of the school hindered the implementation of the TDSB STEM strategy.

Teachers, on the other hand, perceived that the largest barrier was having a limited availability of professional learning opportunities. Fifty-seven percent (57%) of teachers
strongly agreed, agreed, or somewhat agreed that a lack of professional learning was an issue. Interestingly, teachers felt very strongly that a lack of leadership from the school principal was not a problem in regards to the STEM implementation. Indeed, 84% of teachers strongly disagreed, disagreed, or somewhat disagreed that a lack of leadership and support from the school principal hindered implementation of the TDSB STEM strategy. Teachers also felt that non-supportive teachers and the culture of the school did not hinder the STEM implementation. Sixty-one percent (61%) of teachers strongly disagreed, disagreed, or somewhat disagreed that the culture of the school hindered the implementation of STEM, while 56% of teachers perceived non-supportive teachers as a barrier to implementation (see Figures 79 and 80).

Summary: Teachers and administrators were asked a series of questions about barriers to the implementation of the TDSB STEM strategy. Administrators felt that the largest problem was a lack of needed resources, followed by a lack of teacher content knowledge of STEM. Teachers, on the other hand, felt that the largest problem was a limited availability of professional learning opportunities.

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**Figure 79: Barriers to STEM Implementation (Administrators)**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree 1</th>
<th>Disagree 2</th>
<th>Somewhat Disagree 3</th>
<th>Somewhat Agree 4</th>
<th>Agree 5</th>
<th>Strongly Agree 6</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>The culture of the school hinders implementation of the TDSB STEM initiative.</td>
<td>26% (13)</td>
<td>32% (16)</td>
<td>8% (4)</td>
<td>22% (11)</td>
<td>4% (2)</td>
<td>8% (4)</td>
<td>2.7</td>
</tr>
<tr>
<td>Non-supportive teachers hinder implementation of the TDSB STEM initiative.</td>
<td>22% (11)</td>
<td>18% (9)</td>
<td>8% (4)</td>
<td>32% (16)</td>
<td>8% (4)</td>
<td>12% (6)</td>
<td>3.22</td>
</tr>
<tr>
<td>Lack of teacher content knowledge in STEM disciplines hinders implementation of the TDSB STEM initiative.</td>
<td>12% (6)</td>
<td>14% (7)</td>
<td>8% (4)</td>
<td>34% (17)</td>
<td>20% (10)</td>
<td>12% (6)</td>
<td>3.72</td>
</tr>
<tr>
<td>Lack of needed resources (funding, equipment, supplies, etc.) causes issues for implementing the TDSB STEM initiative.</td>
<td>8% (4)</td>
<td>12% (6)</td>
<td>8% (4)</td>
<td>22% (11)</td>
<td>20% (10)</td>
<td>29% (14)</td>
<td>4.2</td>
</tr>
<tr>
<td>Inadequate facilities limit implementation of the TDSB STEM initiative.</td>
<td>14% (7)</td>
<td>22% (11)</td>
<td>16% (8)</td>
<td>26% (13)</td>
<td>10% (5)</td>
<td>12% (6)</td>
<td>3.32</td>
</tr>
<tr>
<td>Overall</td>
<td>16% (41)</td>
<td>20% (49)</td>
<td>10% (24)</td>
<td>27% (68)</td>
<td>12% (31)</td>
<td>14% (36)</td>
<td>3.43</td>
</tr>
</tbody>
</table>

**Figure 80: Barriers to STEM Implementation (Teachers)**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree 1</th>
<th>Disagree 2</th>
<th>Somewhat Disagree 3</th>
<th>Somewhat Agree 4</th>
<th>Agree 5</th>
<th>Strongly Agree 6</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>The culture of the school hinders implementation of the TDSB STEM initiative.</td>
<td>21% (16)</td>
<td>23% (18)</td>
<td>17% (13)</td>
<td>23% (18)</td>
<td>10% (8)</td>
<td>5% (4)</td>
<td>2.95</td>
</tr>
<tr>
<td>Lack of leadership and support from the school principal hinders implementation of the TDSB STEM initiative.</td>
<td>43% (30)</td>
<td>30% (21)</td>
<td>10% (7)</td>
<td>7% (5)</td>
<td>7% (5)</td>
<td>1% (1)</td>
<td>2.09</td>
</tr>
<tr>
<td>Non-supportive teachers hinder implementation of the TDSB STEM initiative.</td>
<td>12% (9)</td>
<td>31% (24)</td>
<td>14% (11)</td>
<td>26% (20)</td>
<td>12% (9)</td>
<td>6% (5)</td>
<td>3.14</td>
</tr>
<tr>
<td>Inadequate facilities limit implementation of the TDSB STEM initiative.</td>
<td>8% (6)</td>
<td>22% (17)</td>
<td>21% (16)</td>
<td>21% (16)</td>
<td>14% (11)</td>
<td>14% (11)</td>
<td>3.55</td>
</tr>
<tr>
<td>Limited availability of professional learning opportunities is an issue.</td>
<td>6% (4)</td>
<td>9% (6)</td>
<td>28% (19)</td>
<td>24% (16)</td>
<td>15% (10)</td>
<td>19% (13)</td>
<td>3.90</td>
</tr>
<tr>
<td>Overall</td>
<td>18% (66)</td>
<td>23% (96)</td>
<td>18% (66)</td>
<td>20% (75)</td>
<td>12% (43)</td>
<td>9% (34)</td>
<td>3.12</td>
</tr>
</tbody>
</table>
Feedback on Coaching Model

Teachers and administrators were asked for their feedback on the model of coaching currently being used in the implementation of the TDSB STEM strategy. Most administrators and teachers felt that the STEM Learning Coach model was an effective approach for professional learning, with 80% of administrators and 73% of teachers reporting that it was very effective or moderately effective. In comparison, there was a sizable percentage of teachers and administrators who thought that the STEM Learning Coach model was not very effective. Twenty percent (20%) of administrators and 26% of teachers reported that they felt the STEM Learning Coach model was not at all effective or slightly effective (see Figures 81 and 82).

Teachers and administrators who felt that the STEM Learning Model was slightly effective or not at all effective were asked to suggest other models of coaching. Teachers and administrators had similar recommendations which are reported as follows: (1) there was a need for more STEM Learning Coaches, (2) there was a need for STEM Learning Coaches to be on site more consistently and more often, (3) STEM Learning Coaches should be part of the staff, and (4) more experienced STEM Learning Coaches with greater depth of knowledge should be selected. However, administrators and teachers had a few recommendations that differed. Administrators suggested that principals be selected as the leader of the STEM program in the school, while teachers felt that coaches should be a staff member on site who could offer more consistent coaching.

Figure 81: Feedback on Coaching Model (Administrators)

<table>
<thead>
<tr>
<th>Very Effective</th>
<th>Moderately Effective</th>
<th>Slightly Effective</th>
<th>Not at all Effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>56% (28)</td>
<td>24% (12)</td>
<td>12% (6)</td>
<td>8% (4)</td>
</tr>
</tbody>
</table>

Figure 82: Feedback on Coaching Model (Teachers)

<table>
<thead>
<tr>
<th>Very Effective</th>
<th>Moderately Effective</th>
<th>Slightly Effective</th>
<th>Not at all Effective</th>
</tr>
</thead>
<tbody>
<tr>
<td>38% (30)</td>
<td>35% (28)</td>
<td>15% (12)</td>
<td>11% (9)</td>
</tr>
</tbody>
</table>
Types of School Leadership Needed for the Successful Implementation of the TDSB STEM Strategy

Administrators were asked to provide comments to an open-ended question on the survey regarding the types of school leadership needed to enable the successful implementation of the TDSB STEM strategy. The most frequent responses included: (1) providing teaching and administrative support, (2) being a leader, and (3) being open to change (i.e., risk-taking).

The most popular response from administrators was to provide teaching and administrative support. This included support such as access to resources, time for planning innovative programing, and being supportive of new ideas. The second most popular response was being a leader. This included being forward-thinking, having a growth mindset, and encouraging staff. The third most popular response was risk-taking. This behavior was characterized by being open to change, thinking outside the box, and a willingness to think about alternatives. Some administrators also suggested that the principal be given the opportunity to provide professional learning opportunities on STEM, such as being a STEM Learning Coach or facilitating inter-departmental collaboration.

Summary: Most administrators and teachers felt that the STEM Learning Coach model was an effective approach for professional learning. Eighty percent (80%) of administrators and 73% of teachers reported that the STEM Learning Coach model was very effective or moderately effective. On the other hand, there was a sizable percentage of teachers and administrators who felt the STEM Learning Coach model was not very effective. Twenty percent (20%) of administrators and 26% of teachers reported that the STEM Learning Coach model was not at all effective or slightly effective.

Teachers and administrators who thought that the STEM Learning Coach model was slightly effective or not at all effective were asked to suggest other models of coaching. Following is a summary of other models of coaching suggested by both teachers and administrators:

- Hire more STEM Learning Coaches
- STEM Learning Coaches need to be on-site more consistently and more often
- STEM Learning Coaches should be part of the school staff
- More experienced STEM Learning Coaches with greater depth of knowledge should be selected.

Notable differences between teacher and administrator survey results include: Administrators recommended that principal be the leader of the STEM program in the school. Teachers recommended that: (1) coaches become a school staff member who works on-site and who can offer more consistent coaching, and (2) there be a hybrid classroom teacher/coach.
Summary: Administrators were asked an open-ended question about the types of leadership needed to enable the successful implementation of the TDSB STEM strategy. The most frequent responses included:

- Providing support (e.g., be supportive, provide access to resources, provide time for planning innovative programming)
- Being a leader (e.g., forward-thinking, growth mindset, encouragement)
- Risk taking (e.g., openness to change, thinking outside the box, willingness to think about alternatives)
- Providing professional learning opportunities (e.g., STEM Learning Coaches, collaboration among departments).

Recommendations for Implementation of STEM
Teachers and administrators were asked about their recommendations for moving forward with the STEM implementation. Both teachers and administrators believed that there needed to be additional funding for more resources, such as more coaches, lessons plans, and new technology and classroom laptops. Another important recommendation made by both teachers and administrators was to allow more time for the TDSB STEM strategy to develop and give it our continued support. As one respondent commented: “If it is going to be truly effective, staff will need time to learn it. This means: It cannot be forgotten in a year or two's time as many past initiatives have been.”

There were also some differences among teachers’ and administrators’ recommendations. Administrators recommended continuing with STEM Learning Coaches with possibly a few changes such as: (1) having more STEM Learning Coaches, (2) having STEM Learning Coaches on-site more often or as part of the staff, (3) having STEM Learning Coaches who are consistent and have specified daily/weekly hours and, (4) having STEM Learning Coaches coming with greater depth of knowledge. Administrators also felt there was room for improved coordination of such matters as timetables and release time, and possibly professional learning for administrators on STEM. On the other hand, teachers recommended integrating STEM with the arts, having more professional learning opportunities, and having a designated classroom for STEM.
Summary: Teachers and administrators were asked to provide recommendations for moving forward with the implementation of the STEM strategy. Both teachers and administrators believed that there needed to be additional funding for more resources, such as more coaches, lessons plans, new technology and classroom laptops. Another important recommendation from both teachers and administrators was to allow more time for the STEM strategy to develop and give it our continued support.

Other Recommendations Include:
- Administrators felt there needs to be improved coordination of such matters as timetables and release time, and that administrators would need professional learning on STEM.
- Administrators recommended continuing with STEM Learning Coaches with possibly a few changes such as:
  - Having more STEM Learning Coaches
  - STEM Learning Coaches being on-site more often or part of the staff
  - STEM learning Coaches having consistent and specified daily/weekly hours
  - Having STEM Learning Coaches with greater depth of knowledge.
- Teachers recommended integrating STEM with the arts, having more professional learning, and having a designated classroom for STEM.

Additional Comments
Teachers and administrators were asked if they had any additional comments for the survey. Both teachers and administrator feel the STEM initiative is a good program, but they have suggestions to make it more effective. These include the following: (1) STEM Learning Coaches should be a more part of the school including having more time at each school and attending school meetings, (2) schools need to continue their collaboration with other schools, (3) recognize the role of the arts in STEM, (4) provide more funding for resources, (5) less confident teachers should be placed with coaches, not the more confident risk-taking teachers, and (6) STEM should be a school-wide initiative. In terms of the STEM Learning Coaches, a concern of many administrators and teachers is that STEM Learning Coaches are assigned to too many schools. It was suggested that each coach have fewer schools and devote more time to each school. In addition to this, some expressed the view that not all the coaches are equally effective.
OVERALL CONCLUSIONS AND RECOMMENDATIONS

What can we learn from the first year implementation of the TDSB STEM strategy, including the factors that hinder its implementation?

Overwhelmingly, teachers and administrators would like the STEM implementation to be continued. Teachers and administrators felt strongly about the importance of STEM education to improve student learning. Teachers and administrators believed that STEM education can help prepare students with the skills and competencies they need. They also agreed that it helped to enhance student learning, solve real-world problems, and engage students in inquiry- or problem-based learning. On the other hand, some administrators and teachers felt the STEM transdisciplinary approach can diminish the individual importance of each content area. In addition, some teachers had the perception that STEM is a “fad”; however, administrators believed that STEM is an educational initiative here to stay.

Teachers and administrators made the following recommendations to support the implementation of STEM:

• Continued and consistent access to STEM Learning Coaches
• More time for planning and collaboration
• More resources (i.e., unit plans, technology, activities)

Summary: Both teachers and administrators feel that the STEM initiative is a good program, but they have suggestions to make it more effective.

Comments Regarding STEM Learning Coaches:

• STEM Learning Coaches should be present at departmental head meetings, staff meetings, inter-departmental meetings, etc.
• STEM Learning Coaches are assigned to too many schools. Each coach should have fewer schools and devote more time to each school
• Not all coaches are equally effective
• Less confident teachers should be placed with coaches, rather than confident risk-taking teachers.

Other Comments:

• More funding is needed for resources
• STEM should be school-wide
• Schools need to continue their collaboration with other schools
• Recognize the role that the arts play in STEM.
• Best practices/ teaching strategies for STEM
• More professional learning (e.g., more STEM Learning Coaches needed, more PL sessions)
• Time to observe others teaching
• More partnerships, school to school and between schools and outside organizations
• Clearer directions on how to cover the curriculum and include STEM activities.

In regards to barriers to the STEM implementation, administrators felt that the largest barrier is the lack of needed resources, followed by a lack of teacher content knowledge of STEM. Teachers, on the other hand, felt the largest barrier was the limited availability of professional learning opportunities.

In terms of resources, while all the schools received STEM resource kits, other resources including STEM monographs and interactive probeware and software technologies were not as widely received. Only 22% of schools received STEM monographs and 28% received interactive probeware and software technologies. This may be a factor that hindered the implementation.

Most administrators and teachers felt that the STEM Learning Coach model was an effective approach for professional learning. Administrators and teachers felt that STEM Learning Coaches provided effective professional learning opportunities; however, they both felt there were some areas that could be improved upon such as: (1) providing career information, (2) assisting with STEM start-ups, and (3) developing assessment criteria for STEM.

The following suggestions were made to improve the coaching model:

• Hire more STEM Learning Coaches
• STEM Learning Coaches need to be on-site more consistently and more often
• STEM Learning Coaches should be part of the staff
• More experienced STEM Learning Coaches with greater depth of knowledge should be selected
• Administrators recommended allowing principals to be the leader of the STEM program in the school.

Following is a further discussion of what we can learn from the first year implementation from the perspective of STEM Learning Coaches, students, teachers, and administrators.
STEM Learning Coaches
STEM Learning Coaches would like to have more ongoing training and training focused on: (1) dealing with educator pushback, (2) providing more direction on how to coach, and (3) assessment and evaluation strategies for STEM teaching and learning.

Students
The results demonstrate that students’ STEM skills and competencies could be better fostered and improved in the following areas: (1) connecting with students in different parts of the world, (2) using technology to share information with others, and (3) improving student time management skills.

The results demonstrate that students are very interested in STEM careers. However, students feel that teachers and guidance counsellors could have more discussions with them about potential career options and preparing for post-secondary education.

Teachers
Teachers feel that they have an understanding of the following: inquiry-based learning, problem-based learning, how to use various STEM-related technologies, and understanding the importance of integration of different content areas when teaching. However, one area of STEM pedagogy that teachers feel they could improve in is the engineering design process.

The most common practices teachers used to teach STEM are: (1) using technology to share information, (2) having students take initiative when confronted with a difficult question, and (3) using technology to support team work and collaboration.

The least commonly used practices to teach STEM are: (1) having students choose their own topics of learning or questions to pursue, (2) discussing issues related to global interdependency, and (3) creating joint projects using contributions from each student.

Most teachers feel that they have tried to develop students’ STEM skills, but some teachers find it difficult to effectively assess STEM skills.

Overall, teachers are confident in their ability to teach STEM effectively, and they feel they are continually improving their STEM teaching practice; however, some teachers question whether they have the necessary skills to teach STEM.
Administrators report that most of the pilot schools (76%) are at the Partial Implementation stage. The Partial Implementation stage refers to the fact that STEM methodology is being implemented in training, but not all teachers are implementing it yet. The remaining schools are at the Full Implementation stage (16%) or Preparation stage (8%) (Gjøvik, 2013).

Administrators were asked about what types of leadership the principal should provide to enable the successful implementation of the TDSB STEM strategy. The top results included:

- Providing Support (e.g., be supportive, access to resources, provide time for planning innovative programming)
- Being a Leader (e.g., forward thinking, growth mindset, encouraging)
- Risk-taking (e.g., open to change, thinking outside the box, and willingness to think about alternatives)
- Providing Professional Development (e.g., STEM Learning Coaches, collaboration among departments)

Lessons Learned from the First Year Implementation of the TDSB STEM strategy
Overwhelmingly, teachers and administrators would like the STEM implementation to be continued. In fact, 98% of administrators and 82% of teachers said they would like the STEM implementation to be continued.

Teachers and administrators feel strongly about the importance of STEM education to improve student learning. Teachers and administrators believe that STEM education can help prepare students with the skills and competencies they need. They also agree that it helps to enhance student learning, solve real-world problems, and engage students in inquiry- or problem-based learning. On the other hand, some administrators and teachers feel that the STEM transdisciplinary approach can diminish the individual importance of each content area. In addition, some teachers have the perception that STEM is a “fad”, while administrators believe that STEM is an educational initiative here to stay.

Both elementary and secondary school students believe that STEM education helps with engagement and helps them learn new information. They also feel strongly that the STEM skill they have developed the most is respect, while the area in which they need more development is time management.
Administrators and teachers reported that STEM Learning Coaches provide excellent support in the following areas:

- Providing STEM teaching and learning resources
- Supporting teaching in using the STEM resource kits and monographs
- Providing professional learning focused on hands-on learning experiences
- Co-planning with teachers and assisting with classroom lessons and programs.

Administrators and teachers feel that STEM Learning Coaches could improve their support in the following areas:

- Providing career information
- Assisting with STEM start-ups
- Developing assessment criteria for STEM.

Overall, teachers are confident in their ability to teach STEM effectively. Teachers feel that they are continually improving their STEM teaching practice; however, some teachers (40%) question whether they have the necessary skills to teach STEM.

Teachers report that they regularly use a variety of teaching practices that support creativity and innovation, such as students generating their own ideas, or inventing a solution. However, teachers rarely have students create an original product to express their ideas or foster global connections.

Teacher Knowledge of STEM:

- Teachers feel that they have a good understanding of the STEM pedagogy (inquiry-based learning, problem-based learning, technology) and resources.
- Teachers feel that they could improve in their knowledge of the engineering design process and awareness of STEM careers.
- Many teachers have not used the STEM education resources on the TDSB’s STEM K-12 Academic Workspace (AW) Site.

Students:

- The results demonstrate that students are very interested in STEM careers. In fact, the most popular career interests among secondary school students include: (1) careers that allow them to create or design things, (2) technology, and (3) science.
- Students feel that more could be done in the school to support them with their career choice.
Level of STEM Implementation:

Most of the pilot schools (76%) were at the Partial Implementation stage. The Partial Implementation stage refers to the fact that STEM methodology is being implemented in training, but not all teachers are implementing it yet (Gjøvik, 2013). The remaining schools are at the Full Implementation stage (16%) or Preparation stage (8%) (Gjøvik, 2013).

Most of the schools have implemented the following activities and processes to implement the TDSB STEM strategy: (1) STEM Learning Coach, (2) professional development, (3) inter-departmental learning and teaching, and (4) upgrades to technology.

Factors Hindering the Implementation of the TDSB STEM Strategy

Administrators felt that largest problem was a lack of needed resources, followed by a lack of teacher content knowledge of STEM. Teachers, on the other hand, felt the largest problem was a limited availability of professional learning opportunities.

A lack of STEM resources was a problem for some pilot schools. Only 22% of schools received STEM monographs and 28% received interactive probeware and software technologies.

STEM Learning Coaches felt a problem with implementation was receiving only somewhat effective training. They would like their training to focus on: (1) dealing with educator pushback, (2) more direction on how to coach, and (3) assessment and evaluation strategies for STEM teaching and learning.

Recommendations for Moving Forward

Overall, teachers, administrators, and STEM Learning Coaches would like to see the TDSB STEM strategy continue. Both teachers and administrators think that we should allow more time for the TDSB STEM strategy to develop and give it our continued support.

Both teachers and administrators believe that there needs to be additional funding for resources, such as more coaches, lessons plan, new technology and classroom laptops. Following are recommendations from teachers, administrators, STEM Learning Coaches, and students.
Teachers and administrators would like to see the following changes during the continued implementation of STEM:

- Continued and consistent access to STEM Learning Coaches (e.g., hire more coaches, STEM Learning Coaches need to be on-site consistently with dedicated hours, more time with coaches, coaches being a part of staff meetings, more experienced coaches, etc.)
- More resources (i.e., lesson plans, unit plans, classroom laptops, technology, activities)
- More funding (i.e., to buy resources, purchase supplies)
- More time for planning and collaboration
- Best practices/ teaching strategies for STEM (i.e., assessment strategies)
- More professional learning (i.e., observation of other teachers, workshops, peer teaching, etc.)
- Clearer directions on how to cover the curriculum and include STEM activities
- More partnerships, school to school and between schools and outside organizations.

STEM Learning Coaches would like:

- More professional learning focusing on teacher pushback, assessment strategies, and effective coaching techniques
- Time to collaborate with other coaches
- More time at each school.

Students need:

- More individual time discussing STEM careers
- More time developing time management skills
- More emphasis on making global connections
- Using technology to share information with others.
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