DECODING STEM: THE IMPACT OF SCIENCE, TECHNOLOGY,
ENGINEERING, AND MATHEMATICS (STEM) OUTREACH
PROGRAMMING ON ENGLISH LANGUAGE LEARNERS

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Abstract

Science, technology, engineering, and mathematics (STEM) are often considered to be "gatekeeping" school subjects. The language used in STEM education and traditional pedagogies – which place emphasis on textbook learning – can be challenging for students, especially those who are learning English at the same time. This case study examines a cohort of English Language Learners (ELLs) selected from a larger longitudinal STEM study that aimed to investigate how school partnerships with STEM outreach programs model alternative pedagogical strategies through hands-on inquiry models to effectively engage ELLs, as well as support STEM learning and second language acquisition (SLA) concurrently. Findings indicate that STEM outreach programs can support attitude, interest, and self-efficacy in both STEM and SLA due to specific distinguishing features. In the context of this study, these features include: (a) access to hands-on learning; (b) agency by design; and (c) access to peer learning networks. Jointly, self-efficacy, attitude, and interest come together to support ELLs in STEM over time.

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Chapter 1: Introduction

Canada's education system has been described as undergoing a period of transition from a model reflective of the industrial era to a 21st century one (Fullan & Langworthy, 2014; Partnership for 21st Century Learning, 2014). In the context of this transition, science, technology, engineering, and mathematics (STEM) has been applauded for its importance in the future economy (DeCoito, 2016; Grisanzio, 2016). The interdisciplinary nature of STEM, as well as its potential to foster 21st century skills, such as creativity, problem-solving, and higher order thinking (DeCoito, 2014), highlight the need for STEM pedagogical intervention at the elementary level in schools. The banking model of education (Freire, 2010) typically used in traditional science and mathematics instruction emphasizes a textbook "read and respond" format. This approach focuses on knowledge, comprehension, and some application (Kessler & Quinn, 1987; Krathwhol, 2002). Conventional modes of teaching often pose a challenge for students who are learning STEM content knowledge, as they can be void of strategies that address learning needs in certain populations. In particular, marginalized groups of students (e.g., women, minorities, and individuals with disabilities) often avoid higher education in STEM as a result of a lack of self-efficacy (NSERC, 2010).

The Canadian education system serves a diverse population (Chui, Flanders & Anderson, 2012). In this thesis, I use the term "English Language Learners" (ELLs) to identify an ethnically diverse group of students who are learning English while, at the same time, speaking their first language at home (Gere, 2008; Ontario Ministry of Education, 2001; Ontario Ministry of Education, 2008). ELLs enter the Canadian education system with a variety of specific needs. In addition to overcoming language barriers, they are expected to unpack content often at the same rate as students who are proficient in English. Many ELLs "have some educational background

[in] the science content" (Coloma, as cited in Goodman & Hevia, 1996, p. 30). However, the Canadian school language requirements usually imply a "double learning" taking place – the student unpacks content knowledge and at the same time learns the English language. In the banking model of education (Freire, 2010), as reflected in traditional science and mathematics education, textbooks and lectures require ELLs to decode the language content and context concurrently with developing their understanding of STEM content knowledge. This process frequently makes STEM learning more challenging for these students, and can deter them from pursuing STEM education beyond the minimum provincial requirements.

Content-based instruction (CBI) is a pedagogical model used to foster second language acquisition (SLA) in applied linguistics. In CBI, students engage in content instruction and learning without explicit effort to learn the language separately through meaningful content-based activities (Richards & Rodgers, 2001). Outreach programs have the potential to support both STEM learning initiatives as well as SLA for ELLs through hands-on inquiry-based pedagogical modeling in CBI. In teaching STEM content using outreach programs for CBI, traditionally marginalized groups, such as ELLs, have access to STEM content knowledge despite language barriers. If ELLs can interact with STEM education, then perhaps the space between comprehension and communication can potentially diminish. If this is the case, the simultaneous formation of both STEM and second language (L2) identities, fostered around positive attitudes and interest in STEM by grade eight, can potentially promote student entry into future STEM pathways (Cannady, Greenwald & Harris, 2014). My research explores the potential of an inquiry-based hands-on outreach program to: (a) engage ELLs, and (b) introduce STEM content and the English language cohesively, thus supporting ELLs' participation in the international post-secondary STEM arena.

1.1 Scope, Context and Purpose of Study

In my thesis, I analyze a case sample of ELLs taken from a larger 3-year STEM longitudinal study that involved a four-way partnership between Western University, four middle schools from a public-school board in the Greater Toronto Area, a STEM outreach program (STOp), and a biotechnology company. The larger study has four goals: (a) to engage students and teachers in STEM education; (b) impact students' attitudes and interest towards STEM; (c) impact interest in STEM education and careers; and, (d) impact STEM professional development. Each of these goals is sensitive to disconnections between STEM education in schools and STEM pathways that ultimately result in a shortage and lack of diversity in STEM educational attainment and, ultimately, undermine the formation of a STEM literate society (Bybee, 2013; DeCoito, Steele, & Goodnough, 2016). Research in STEM education confirms that the interdisciplinary approaches towards the four subjects in the context of real-world problem-solving often has a positive impact on both attendance and achievement in STEM disciplines (Satchewell & Loepp, 2002; Sinay, Jaipal-Jamani, Nahornick & Douglin, 2016).

The STOp outreach program is a Canadian charitable organization that provides STEM workshops in Ontario and Alberta. These workshops seek to bring together the community, STEM industry and the education system to support students during their formative (K-8) years. For this thesis, STOp is based in the Greater Toronto Area and therefore, explores workshops in the context of the Ontario curriculum standards. The goal of the STOp is "… to ignite scientific wonder in children through investigative half-day workshops, guided by the knowledge of scientists and engineers" (STEM Outreach Program [STOp], 2013; DeCoito et al., 2014). Myszkal (2016) notes that when schools collaborate with a STEM outreach program, students are given access to: (a) STEM as an interdisciplinary and practical framework rather than

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dissected and often decontextualized subjects; (b) STEM materials for hands-on learning; (c) time for inquiry and exploration in STEM; and, (d) a diverse team of STEM professionals to facilitate the workshops (p. 5-7). The foundational underpinnings of STEM outreach programs have a positive impact on diverse learners (Sithole et al., 2017). Difficulties encountered by ELLs at the middle school level in situating themselves as both multilingual learners and STEM participants are reduced in STEM outreach programs as they receive a myriad of benefits from outreach learning experiences. Not only are their perceptions of STEM and familiarity with STEM concepts addressed, but also the acquisition of language and communication in their L2.

 1.1.1 Considering Canada's Diversity. STEM degrees are considered globally transferable (Nelson, 2014; UK Commission for Employment and Skills, 2011). On January 1st, 2015, the government of Canada introduced the Express Entry Immigration System, which includes the Federal Skilled Worker Program, in an effort to acquire more skilled workers to fulfill the economic needs of the country (Government of Canada, 2017). Within this system, there is a provision for express entry of applicants who, in addition to meeting minimum criteria of admission, have received training and acquired work experience in any of the 347 eligible occupations (Immigration Canada, 2017). The list of qualified professions places a significant emphasis on various STEM careers, including engineering managers, architecture and science managers, physicists and astronomers, civil engineers, and computer programmers and interactive media developers – to name a few (Immigration Canada, 2017). The non-STEM careers on the list indicate a need for STEM skills such as record keeping, reading and understanding technical materials, and creative problem-solving (Texas GEAR UP, 2017). These skills are important and relate to the conceptualization of STEM education mentioned above.

Canada currently has the second highest (20.6%) immigration population of the G8 next to Australia (26.8%) (Organization for Economic Cooperation and Development, 2016). Additionally, the growth of the immigrant population in Canada has replaced the natural increase that currently accounts for less than one-third of Canada's population growth (Statistics Canada, 2017). The top three provinces for immigration settlement are Ontario, British Columbia, and Quebec (Chui, Flanders & Anderson, 2011; King, 2009). Toronto, the capital city of Ontario, has been dubbed "the most multicultural city in the world" (Kuzmin, Motskin & Gallinger, 2015). This study takes place within the Greater Toronto Area (GTA), which comprises Toronto and its suburbs. Figure 1 illustrates the proportion of migrant population in the GTA.
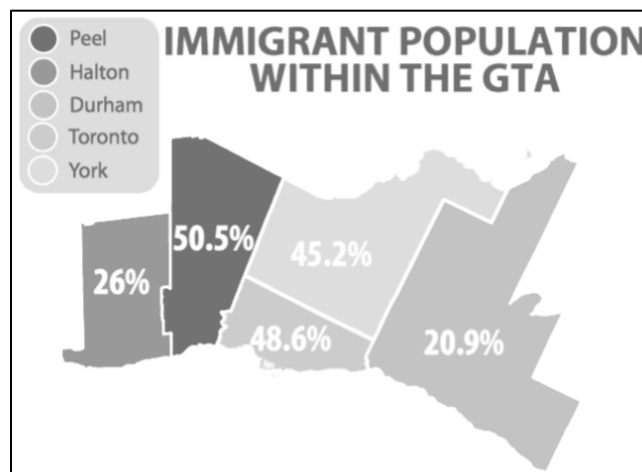
Figure 1. Immigrant population within the GTA (Statistics Canada, 2011 as cited in Region of Peel, 2013, p. 3)

STEM education incorporates a variety of scientific terms that can be difficult to understand for learners whose first language differs from the language of instruction. The presence of a language barrier makes the process of learning through traditional STEM pedagogies potentially difficult for ELLs. Outreach programs such as STOp aim to provide students with experiences in STEM that bridge the theories and real-life contexts, while also including hands-on learning experiences intended to familiarize students with STEM concepts.

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This approach relies less on language and more on inspiring students in a fun and engaging way. For ELLs, the approach used by the STOp is "naturally differentiated" and seeks to give students autonomy over their learning. This autonomy is valuable because while these students are integrated with English-speaking peers, they can further navigate both their language and STEM learning concurrently.

    1.1.2 Why STEM? An Ontario curricular context. The current structure of middle school in Ontario often initiates a rotary system for grade seven and eight students (and some grade six) (Toronto District School Board, 2006). As a result, teachers work in a "specialized" manner based on their teachable(s) – for example, science teachers teach science and may or may not teach mathematics as well. Thus, the Government of Ontario has a series of curriculums that isolate standards for each given subject. In STEM education, these are the *Science and Technology* curriculum (Ontario Ministry of Education, 2007) and the *Mathematics* curriculum (Ontario Ministry of Education, 2005). The subject of "engineering" is split between the two curriculums, without explicit indication of how mathematics and science overlap.

    The interdisciplinary nature of STEM education is often conceived of as distinct from the current practice of teaching each discipline of science, technology, engineering, and mathematics in isolation. Although there is no universal definition of STEM outside of the four subjects within the acronym (Bybee, 2010), many professionals in education understand STEM education as *interdisciplinary* and promoting *active* learning (Figure 2). This conceptualization includes embedding problem-solving and inquiry, as well as active engagement of students with STEM content, rather than exposure to strictly theoretical STEM knowledge through two-dimensional textbooks, images, and chalk 'n talk pedagogies. As depicted in Figure 2, STEM education

bridges theories into real-life contexts by providing experiences relevant to the application of STEM through "exploring", "doing", "observing," and "experimenting".
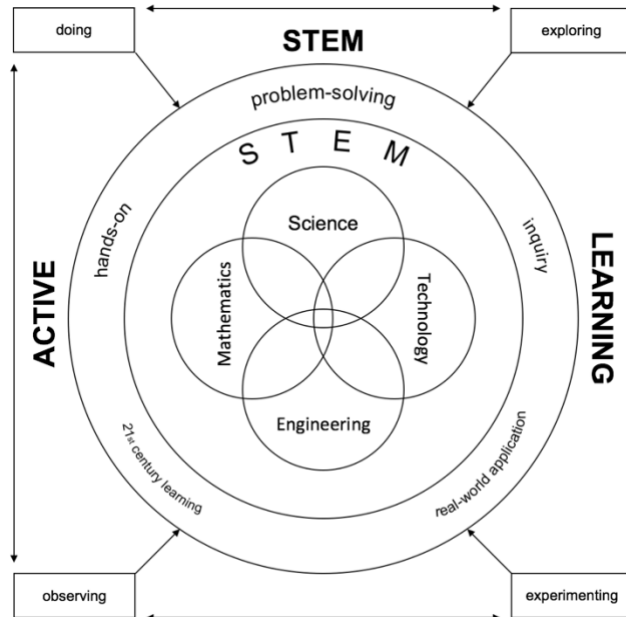
Figure 2. Integrated STEM learning and associated factors

Not only does STEM seek to promote collaborative understanding between and across the disciplines, there is also an applied understanding of the four subjects highlighted through action. DeCoito (2016) provides a knowledge synthesis exploring STEM in Canada according to various stakeholders including STEM education postsecondary faculty members. According to DeCoito (2016), STEM is often described as:

> a transdisciplinary field in which real problems of the world get undertaken. Problems that require science, technology, engineering and mathematics brought to bear in order to be able to solve the problem or address the issue or the concern that is manifested. It

cannot be solved adequately by just one of the disciplines or one of the fields; it's a field

unto itself (Interview with a STEM education faculty member, 2015).

The definition above incorporates discipline overlap while bringing forth the active and applied

components of STEM as a whole. Thus, the definition differs from the one supplied in the

current Ontario curriculum standards. The existence of such does not insinulate a negative

conception of science and technology, as well as mathematics, as explored in schools. Rather, I

point to this difference to highlight how each definition complements the other to support

students' perceptions of themselves within the four disciplines and the impact of STEM

education on the learner. The Ontario Science and Technology Curriculum (Ministry of

Education, 2007) centres on science and technology literacy (including theories surrounding the

nature of science) as a foundation for science and technology curriculum expectations. For this

curriculum document, the Science Teachers Association of Ontario (STAO) posits that:

> The primary goal of science is to understand the natural and human-designed worlds.
> Science refers to certain processes used by humans for obtaining knowledge about nature,
> and to an organized body of knowledge about nature obtained by these processes. Science
> is a dynamic and creative activity with a long and interesting history. Many societies
> have contributed to the development of scientific knowledge and understanding ...
> Scientists continuously assess and judge the soundness of scientific knowledge claims by
> testing laws and theories, and modifying them in light of compelling new evidence or a
> reconceptualization of existing evidence.

> Technology involves the development and use of materials, tools, and processes for
> solving human problems and helping to satisfy human needs and desires … Science often

uses and requires tools and processes developed by technology, and conversely, technology often employs principles, laws, theories, and processes developed by science. (Cited in Ontario Ministry of Education, 2007, p. 4)

The Ontario Mathematics Curriculum (Ontario Ministry of Education, 2005) considers the practical uses of mathematics as a life skill. Additionally, this document notes the connection between mathematics and other disciplines, including science; however, the structure of the curriculum separates the concepts and often places the onus of recognizing the interdisciplinary relationships on the student – especially if he or she is taught using traditional methods, as illustrated in the document:

> As students identify relationships between mathematical concepts and everyday situations and make connections between mathematics and other subjects, they develop the ability to use mathematics to extend and apply their knowledge in other curriculum areas, including science, music, and language. (p. 3)

Thus, while the curriculum frames theories and knowledge of each discipline by separating the subjects – specifically, as students transition to a rotary system at the intermediate level – teachers and students may find it difficult to make connections between the disciplines and implementing them in a real-life context. For ELLs, the ability to make these connections is further impeded by the presence of a language barrier in comprehending the theories within the disciplines, as well as communicating the complexities and connections between the scientific, technological and mathematical theories. As a result, in differentiating between STEM and the curriculum expectations in Ontario, the definitive foundation lies in the explicitness in providing active and interdisciplinary learning for students.

Cognizant of the need for balance between curriculum expectations *and* interdisciplinary and active STEM learning in a real-life context, STOp, the organization that runs the workshops on which I focus on this thesis, aims to merge curriculum expectations with STEM education and STEM professionals. In combining the Ontario curriculum expectations using a STEM model (Figure 2) STOp provides workshops that emphasize the following: (a) science and technology; (b) mathematics; and (c) combined grade special interest. Although the workshops are aligned with the curriculum and may be either "science forward" or "mathematics forward," they all aim to provide students with the connections between the curriculum content and broader interdisciplinary STEM concepts. In this way, they provide students with opportunities to engage in their STEM education as autonomous agents of their learning. For ELLs, this autonomy provides a series of scaffolding elements that naturally differentiate their learning needs.

1.1.3 Access to STEM manipulatives for hands-on learning. There is a variety of science and mathematics manipulatives available in Ontario schools; however, these materials need to be carefully selected for purchase based on durability, frequency, and access for use across multiple disciplines. Funding in Ontario schools is complex. Given the financial intricacies of providing hands-on inquiry-based learning experiences, outreach programs such as STOp provide hands-on learning and manipulatives at the forefront of their design. In comparison to schools, which have limited funding, specialized STEM outreach programs that work in collaboration with STEM industry partners have better access to a variety of learning materials. For example, in the STOp workshop that explores *Understanding Life Systems – Biodiversity* students investigate a selection of preserved specimens provided by the workshop facilitator. The student participants assume the role of a taxonomist to investigate the diversity of life systems in the environment (STOp, 2013) (Figure 3).

Figure 3. Resources in "Understanding Life Systems – Biodiversity" workshop

Access to such varied materials within schools – due to the process of preservation and storage –
is unavailable. As a result, students are left learning some STEM concepts, using more
traditional science teaching methods (Myszkal, 2016; Qureshi et al., 2016; Sanders, 2009). The
inquiry-based process that STOp workshops make possible supports a wider range of learners
than traditional science teaching methods. In the context of this thesis, ELLs are provided with
richer opportunities to learn using hands-on materials, which are less reliant on language (Lee et
al., 2008) and more exploratory in nature.

1.1.4 Time as a resource for authentic STEM learning. In middle school, science is
often taught on a rotary basis, which can place constraints on instructional time. The benefit of
the rotary method is that students have access to teachers as "specialists" in their subject area.
Unfortunately, the rotary system only allocates forty-minute class periods to students at the
intermediate level (grades 7-10). Occasionally, students may have two periods on the same
subject area one after another; however, this is not a regular occurrence. Forty minutes is not a
lot of time to conduct inquiry without cognizant and detailed preparation from the teacher. In
comparison, STOp workshops include half-day programs of two and a half to three hours during
which students explore STEM using a variety of pedagogical methods. Students are provided

ample time to investigate manipulatives, and in the case of ELLs, practice their L2 in a low-anxiety learning environment with their peers. Furthermore, students have time to witness the connections between the disciplines without any interruptions.

1.1.5 STEM industry professionals as facilitators of learning. Although the rotary system does provide students with specialized science educators, the connection and application to other STEM disciplines is not always present. Nieto (2011) comments that teachers' pedagogical creativity is often impaired by curricular subject expectations over time (p. 190). In contrast, STOp involves in its workshops community members who are active in STEM industries. For example, the workshop that explores *Structures and Mechanisms – Form and Function* is facilitated by a civil engineer. These professionals combine work experience and content knowledge, which can differ from experiences provided by classroom teachers. When teachers rely on textbook learning, they are generally bound by the interpretation of the textbook. In contrast, having STEM industry experts to complement the various approaches to teaching science and technology education in schools supports student learning through practical knowledge and experience.

1.2 Research Questions

In this thesis, I explore the following research questions:

1. Do STEM workshops, as a form of CBI, affect middle school ELLs attitudes and interests in STEM over time?

2. Do STEM workshops affect ELLs self-efficacy, in terms of fostering both STEM and L2 identities in middle school students?

1.3 Context of the Study

The STEM education literature indicates that middle school is a crucial time to establish positive attitudes, interests, and self-efficacy in students as they transition towards more abstract science content (Mattern & Schau, 2002; Mohr-Schroeder et al., 2014; President's Council of Advisors on Science and Technology, 2010). Student vulnerability can increase during middle school when you include factors such as race, gender and socioeconomic background (Elam, Donham & Soloman, 2012; Mohr-Schroeder et al., 2014). Without careful attention to these factors, a large population of students becomes removed from STEM pathways. The larger STEM longitudinal study, a part of which I analyze in this thesis, commenced in 2013 in partnership with four highly diverse middle schools considered somewhat high on the social risk index (SRI). SRI is a numerical score (0-9) that incorporates the following variables:

- average household income;

- unemployment rate;

- proportion of residents 15 years and older who lacked a high school diploma;

- proportion of owner-occupied dwellings;

- mobility over one year;

- knowledge of Canada's official languages;

- proportion of recent immigrants;

- lone parent families; and,

- reliance upon government transfer payments (HRSDC, 2008; Ontario School Board [OSB], 2008).

My study focuses specifically on the experiences of a cohort of ELLs from a school to which I refer as Trillium Street Middle School (a pseudonym). For all schools involved in the broader

study, a calculation of social risk was completed twice: first in 2006, before the initiation of

Phase I of the study, and then again during Phase II in 2014. Table 1 presents the level of social

risk of the schools involved in the study. During the larger study, Trillium Street Middle School

remained in the *somewhat high-risk* category; however, the score shows small decline over time.

Table 1

Social Risk Scale and Breakdown by School

Social Risk Scale		*Social Risk Breakdown by School*		
Scale	Score	School	2006	2014
High Risk	7-9	Trillium Street Middle School	6.335	5.684
Somewhat High Risk	5-6	School 2	6.174	6.069
Somewhat Low Risk	3-4	School 3	6.577	7.093
Low Risk	0-2	School 4	6.609	3.177

Note. Data for the social risk scores by school provided by the Ontario School Board (2008 & 2014)

Two variables, "recent immigration" and "knowledge of Canada's official language," are

pertinent to this case study. They indicate that Trillium Street Middle School needs to consider

the population and support learning in a way that is reflective of the needs of students within the

community. When the ELL SRI community variables are isolated, data shows that the

community has a total of 3225 recent immigrants who account for 15.8 percent of the population

in the area. Additionally, 21 percent of the community's families are considered low income

(before tax) (Ontario School Municipality [OSM], 2006) and 4.5 percent of the population in the

area speak neither of Canada's official languages (OSM, 2006). For this reason, Trillium Street

Middle School has an established ESL program within the school. However, given the

integrative policy surrounding ESL programs, ELLs still need access to their content learning –

and content core educators that can successfully foster their linguistic and cultural needs. As a

result, partnerships with programs such as STOp are valuable as they address ELLs' distinct learning needs.

1.4 STOp Workshop

A typical STOp workshop comprises several components: lectures, a mixture of passive and active demonstrations, and hands-on learning. The first segment of the workshop introduces the big ideas, with some focused instruction, which is followed by a short activity to pique student interest and apply a single concept. Over the course of the workshop, instructors alternate between lecture and/or demonstration model. All lectures and demonstrations are followed by hands-on activities aimed at reinforcing the particular skill or idea. This method compartmentalizes STEM concepts into smaller and more tangible components that, when combined, help students to understand the big idea under investigation. The next step of the workshop is a larger hands-on inquiry project or challenge, which requires an application of all the skills and theories together. This segment is followed by a final consolidation of STEM learning that broadly applies the knowledge to a real-life context (e.g., STEM skills, careers, literacy, etc.) (Figure 4).
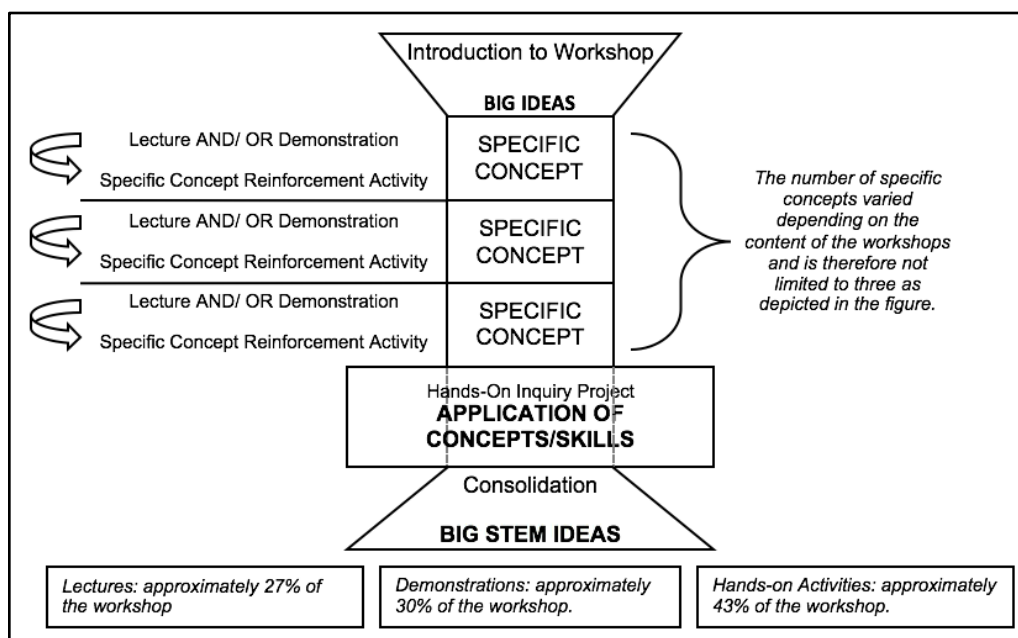
Figure 4. Structure of STOp workshops

The mean amount of time dedicated to each pedagogy within the two and a half hour workshops was calculated to establish the pedagogical distribution of STOp (Figure 4). The calculation used a random sample of six time-stamped running record style workshop observations as well as time-stamped multimedia including photographs and videos. Each observation was categorized as either lecturing, demonstrations, or, hands-on experiments and the amount of time dedicated to each pedagogy was recorded. Because the STOp engages in some lecturing, ELLs were able to effectively compare teaching methods under a consistent context and reflect on which pedagogical approach fulfilled their learning needs most efficiently; thus, aiding in the exploration of ELLs' attitude, interest, and self-efficacy in STEM.

1.5 Significance of the Study

The findings that I present in this thesis can potentially help to support STEM education in Canadian schools. Given the diversity of students in Canada, detaching the acquisition of

language from content makes learning challenging. More specifically, the practice separating language learning through the expertise of one educational expert (the ESL teacher) and the acquisition of science, technology, and mathematics on another (the science teacher, the technology teacher, and the mathematics teacher) places the onus of making connections on the individual student. Given the dissection between language and content education, it is difficult for ELLs to form a positive attitude towards and interest in STEM subjects. Furthermore, when STEM education uses didactic methods that rely heavily on linguistic understanding, ELLs confidence in their skills to pursue STEM learning diminishes. This approach removes ELLs from STEM pathways – not because they are unfit to participate in STEM but because they face a barrier created by the education system. Findings from this study indicate the need for collaboration among ESL teachers, STEM content teachers, and STEM professionals through participation in STEM outreach workshops. Furthermore, the study demonstrates the value of pedagogies used by STOp. Spefically, they point to the advantages of the hands-on inquiry-based approach – a pedagogical approach different from traditional science, technology, and mathematics instructions – used in STOp workshops. This approach fosters autonomy in students regardless of their linguistic ability. The study suggests that such pedagogies can support the development of content-specific teachers' pedagogies so that ELLs have the opportunity to develop their attitudes, interests, and self-efficacy in STEM while concurrently navigating the acquisition of the English language.

1.6 Thesis Outline

This thesis is divided into six chapters. Chapter Two, which follows the Introduction, offers a review of pertinent literature in both STEM education and applied linguistics to showcase the dissection between the fields and identify the gaps in both fields. Chapter Three

provides a theoretical framework for discussing the theories within the disciplines to consider the needs of ELLs within STEM education. These theories include the integrated STEM education framework, self-efficacy theory, second language acquisition, and agency by design. Chapter Four details the methods and tools used in the study and profiles the case study participants. Chapter Five presents the data and findings from the case study. Finally, Chapter Six considers the results through a theoretical lens and discusses the study's limitations, its implications, and areas for future research.

Chapter 2: Review of the Literature

Research on ELLs as participants in STEM education is sparse. The existing literature often emphasizes theoretical discussions rather than empirical data. Furthermore, many sources are from the United States which differs from Canada with respect to policies surrounding immigration and second language acquisition (SLA) in schools. As a result, the literature has been sectioned into the following categories: (a) from science, math, and tech to STEM education; (b) a brief history of gatekeeping in STEM disciplines; (c) self-efficacy in STEM education and/ or SLA; (d) ELLs and STEM; (e) overlapping content-based instruction with STEM education; (f) STEM outreach programs; and, (g) addressing the gaps in the literature. The combination of themes mentioned above implicitly supports this research as they allow for inferred connections between two large fields – STEM education and applied linguistics. These categories inform the need for further research in combining STEM outreach and CBI to foster positive attitudes and interests in STEM education, as well as supporting ELLs' self-efficacy in STEM and SLA.

2.1 From Science, Math, and Tech to STEM Education

The current practice in Canadian junior and high schools is to isolate subjects. The separation between subjects begins during middle school with the introduction of rotary and teachers who specialize in specific disciplines (hereafter referred to as *specialist teachers* for brevity) (Bégin et al., 1994). The argument for separation is that as school content increases in complexity, students should be given access to specialist teachers, who can support individual career pathways (e.g., university preparation, college preparation, etc.) (Byrd-Bennett et al., 2009; Pollock & Mindzak, 2014; Schiro, 2013; Walker, 2002). Pollock and Mindzak (2014) argue that specialized teachers support students through quality programming and planning

based on the teachers' interests, experiences, and skill sets. Furthermore, the Elementary

Teachers' Federations of Ontario (ETFO) stresses that specialist teachers are one of six building

blocks for better schools in Ontario, contending that "staffing elementary schools with teachers

who have specialized training in [music, guidance, physical education, visual or performing arts,

or design and technology] greatly enriches the educational experience of students" (p. 8).

Although specialized education aims to foster student success, the literature indicates that it

places responsibility for making cross-curricular connections on the student. For this reason,

acquiring an interest in the subject matter can be challenging (Drake & Reid, 2010; Kelley &

Knowles, 2016; The Literacy and Numeracy Secretariat, 2010). The Committee on Integrated

STEM Education (2014) emphasizes that "[c]onnecting ideas across disciplines is challenging

when students have little to no understanding of the relevant ideas in the individual disciplines.

Also, students do not always or naturally use their disciplinary knowledge in integrated contexts"

(cited in Kelley & Knowles, 2016 p. 3). For students who face a language barrier or learning

disability, cross-curricular connections are further highlighted and disadvantage these learners.

More recently, the discourse supporting interdisciplinary education has received some

international attention. For example, Finland has removed subject-specific education within its

policies in favour of topic-specific education that integrates multiple subjects in a problem-

solving approach (Garner, 2015; Halinen, 2016; Kauppinen, 2016). Gardner and Boix Mansilla

(1994) suggest that "[b]y combining knowledge from multiple disciplines … learners may

approach subjects too complex to be adequately addressed with the tools of only one discipline"

(as cited in Miller, 2006, p. 1). The need to approach problem-solving with multiple disciplines

was the drive for coining the interdisciplinary acronym known as STEM (Bybee, 2013; Mitts,

2016; Shanahan, Burke & Francis, 2016). The National Science Foundation (NSF) recognized

that although science, technology, engineering, and mathematics tend to be taught separately from one another (Abell & Lederman, 2014; Kelley & Knowles, 2016; Sanders, 2009), these subjects work together when implemented in a real-life context (Bryan, Moore, Johnson & Roehrig, 2016). Mitts (2016) illustrates the connection between STEM and its four components of a whole-problem solution by breaking down each subject into the function. Mitts claims that: (a) science – proposes why: the theory; (b) technology – explains how: the process; (c) engineering – determines what: the design; and (d) math – reveals relationships: the concept (p. 31). While the definition of STEM remains ambiguous, generally there are two schools of thought – that is, a political/ economic goal resonating from the STEM workforce (which emphasize the need for STEM careers for the future) and a goal that comes from the field of education (which emphasizes STEM skills development).

From the political standpoint, there has been global government emphasis on the need to fill STEM occupations. Many countries, including Canada, are moving towards a knowledge-based economy (Cheng, Colijm, Levanon & Paterra, 2012 as cited in Franz-Odendaal, Blotnicky, French & Joy, 2016; Orpwood, Schmidt & Hu Jun, 2012; Policy Horizons Canada, 2013). This economic goal affects policies on immigration (as discussed in section 1.1.1) as well as education in how the curriculum is supporting STEM pathways with a goal of producing STEM workers (National Academy of Engineering and National Research Council of the National Academies [NRC], 2014). With this political train of thought, some educational scholars argue that STEM becomes mechanical, focusing on economic output rather than STEM skills as life skills that produce STEM literate citizens (Siekmann, 2016).

The educational perspective on STEM suggests that the integration of the four subjects highlight their relationships as "allied areas of research" (Shanahan, Burke & Francis, 2016, p.

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130), but subsequently underscores that STEM education is inherently active (Mitts, 2016). Through a combination of the subjects, individuals can solve problems and apply knowledge in a real-life context (DeCoito, Steele & Goodnough, 2016). The active learning component of STEM provides purpose through STEM literacy. STEM literacy consists of:

- knowledge, attitudes, and skills to identify questions and problems in life situations, explain the natural and designed world, and draw evidence-based conclusions about STEM related issues;

- understanding of the characteristic features of STEM disciplines as forms of human knowledge, inquiry, and design;

- awareness of how STEM disciplines shape our material, intellectual, and cultural environments; and,

- willingness to engage in STEM-related issues and with the ideas of science, technology, engineering, and mathematics as a constructive, concerned, and reflective citizen (Bybee, 2013, p. 5).

By fostering the aforementioned in students, they can acquire a sense of innovation, problem-solving, communication, and other 21st century learning skills (Orpwood, Schmidt & Hu Jun, 2012; Partnership for 21st Century Skills, 2002), which organically support the whole learner whether they pursue a STEM career or not.

2.2 A Brief History of Gatekeeping in STEM Disciplines

Gasiewski, Eagan, Garcia, Hurtado, and Chang (2011) define *gatekeeping* the practice of offering post-secondary introductory science and mathematics courses that either explicitly or implicitly filter those with the academic stamina to learn using disengaging pedagogies such as "chalk 'n talk" lectures with exceedingly difficult tasks. Gatekeeping is predicated on the assumption that success in science is explicitly innate rather than developed (p. 229-230). Gasiewski et al. (2011) discuss the impact of gatekeeping practices at the post-secondary level in STEM fields stating that:

> Introductory courses in the sciences have been criticized for their lack of engaging pedagogy and their encouragement of passive learning techniques. Critics have cited these features as primary reasons why students decide to leave the sciences shortly after enrolling in college, as students report feeling un-engaged in learning and confused about course content. (p. 2)

Gatekeeping practices in STEM have a considerable impact on individuals pursuing STEM pathways. This impact is intensified when factors such as gender, race, ability, and language are considered (Basile & Lopez, 2015; Cech, 2013; Charles & Bradley, 2009; Finson, 2002; Legewie & DiPrete, 2014; Sorrells, Cole, Pazey & Carter, 2014; Torres-Velàsquez et al., 2014). As a result, teacher-centered (Fatt, 2000; Kahl & Venette, 2010) didactic/ banking model pedagogies (Freire, 2010; Myszkal, 2016; National Research Council, 2010) accompanied by rote-memorization (Furtado, 2010; Gasiewski et al., 2011; Osburne, 1993) and a lack of relatable identities through diversity in STEM participants, disengage students and potentially remove some populations (such as ELLs) from STEM pathways.

2.3 Self-Efficacy in STEM and/or SLA

Bandura defines self-efficacy as "beliefs about one's capabilities to learn or perform behaviors at designated levels … Much research shows that self-efficacy influences academic motivation, learning, and achievement" (Schunck & Pajares, 2002, p. 2). The literature stresses the value of low anxiety learning environments that encourage "intellectual risk" (Beghetto, 2009) in language and content acquisition to support self-efficacy, as well as foster attitude and interest in STEM (Beebe, 1983 as cited in Kessler & Quinn, 1987; Krashen, 1981). In education, intellectual risk-taking and self-efficacy form a linear relationship (Beghetto, 2009, p. 213). For students to feel safe taking intellectual risks, a certain level of self-efficacy needs to be fostered. The building blocks of self-efficacy include: (a) mastery experiences; (b) observing others; (c) direct persuasion by others; and (d) mood (Bandura, 1977, p. 195; Reivich, 2010, p. 1-2). The foundation of these building blocks is composed of personal and social factors. In his talk about "failure" in STEM inquiry, Rob Stephenson emphasizes that elementary level students do not see an unsuccessful experiment as a complete failure, but rather an approach that did not work out and an opportunity to improve / learn how to improve in the future (TEDx Talks, 2014). This conceptualization encourages students to explore the challenge further and apply various approaches to problem-solving. Maslyk (2016) also investigates failure in the process of "making", stating that:

> Traditional schooling isn't set up for taking risks and accepting failures. We teach the content until we are sure our students understand it, then we test them to see if they have mastered it. Engaging in STEAM and making means that both teachers and students will get a little more comfortable with failure. (p. 45)

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This emphasis on personal inquiry and collaboration with other students potentially fosters self-efficacy in STEM, leading to intellectual risk-taking.

Similar to STEM education, certain "risk" factors emerge when students are learning to communicate educational content in a second language and are affected by the learning environment, pedagogies, and self-confidence (Allen & Franklin, 2002, p. 8; Liu & Chen, 2015). When ELLs are segregated in separate English as a Second Language (ESL) classes, student performance anxiety decreases; however, the binary between content-based classrooms and language learning classrooms fails to integrate students' language learning with content. Secondly, this separation segregates ELLs from their English-speaking peers. Dörnyei (2014) refers to the following three affective influencers of L2 acquisition: (a) the ideal L2 self – the learner's perceived ideal in learning another language that motivates the learner through closing the gap between the actual and ideal self; (b) the ought-to L2 self – the skills and attributes the learner believes he or she needs in order to avoid negative outcomes in L2 acquisition; and (c) L2 learning experience – specific to the learning environment and L2 learning process (p. 521). These influences parallel theories around academic self-efficacy in STEM education (Bandura, 1982; Schunck & Pajares, 2002). If ELL students are to acquire STEM content and a second language in a manner that enhances positive attitudes and increases interest in both their L2 and STEM, and at the same time develop an identity within these areas, then self-efficacy is of paramount importance. Students need a program that allows their self-efficacy to flourish, which points to the limitations current models of segregated language teaching and traditional STEM pedagogies.

2.4 ELLs and STEM

STEM disciplines carry a series of vocabulary that can be difficult for students, including native English-speaking students, to understand (Lee, Quinn & Valdés, 2013; Lo, 2014). Cummins (1984) distinguishes two types of English proficiencies. The first is basic interpersonal communicative skills (BICS), or conversational L2 proficiency where the ELL student can communicate fluently with others who speak English. BICS usually develops quickly, within the first few years of second language immersion. The second type of English proficiency is cognitive academic language proficiency (CALP), which considers fluency from the ability to engage in the abstract/decontextualized written and spoken form in academic contexts. The language used for academic purposes is more challenging to acquire and is not regularly used in "playground" conversation environments (Cummins, 2008; Gibbons, 1991). CALP takes anywhere from five to seven years to develop. As Hoffman and Zollman (2016) stress:

> Academic language is much more cognitively demanding and often appears in situations without many context cues (such as a non-illustrated reading passage or a lecture-style lesson without visuals or manipulatives). This more difficult type of English encompasses general academic language that students are unlikely to hear in social situations (phrases like "select the most likely response from the following options" or "multiply by the conjugate") as well as content-area technical terms (including STEM terminology with multiple meanings; e.g., *plane* or *receptacle*). (p. 85)

Like Cummins, other scholars from the field of applied linguistics differentiate academic and conversational language (Biber, 1986; Corson, 1995; Gibbons, 1991; Cummins, 2008) to argue that the acquisition of an additional language is not a linear process (Cummins, 1984; Hoffman

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& Zollman, 2016). The distinction between the two proficiencies emphasizes that while individuals may be able to engage in conversational English, they may still need support in their academic language development (Hoffman & Zollman, 2016; Lillywhite, 2011).

When working with students who are learning the English language and STEM content, communication of STEM knowledge and understanding becomes challenging. At the same time, the literature notes that ELLs do still need to acquire academic language proficiency and the skills to be able to interpret language in an abstract context – specifically in the context of STEM terminology (Cummins, 1984; Hoffman & Zollman, 2016). Krashen's theory of SLA (1981) emphasizes that students need "comprehensible input" in low-anxiety environments, in which they are motivated to communicate about a given topic without fear of precise grammar. The literature also suggests that "teachers should not assume that [ELL] students will somehow absorb academic language through mere exposure to it" (Manitoba Ministry of Education, 2014, p. 15). Lee at al. (2008) proposes that hands-on activities carry less of a linguistic burden on ELL students (as cited in Shanahan, Pedretti, DeCoito & Baker, 2011). Nevertheless, ELLs still need scaffolding for their L2 identities to be fostered in the process of learning STEM content (Gibbons, 2006). The findings of Lewis et al. (2011) suggest that science activities provide ELLs with "structured opportunities for developing English proficiency in the context of authentic communication about science" (p. 157 as cited in Frank, 2011, p. 10). In considering these findings – which parallel CBI in applied linguistics –indicates that ELLs can still develop their abstract STEM academic language by making it contextual through hands-on STEM activities (Gibbons, 2006). After this contextual exposure, ELLs can develop their STEM academic language and infer abstract content more efficiently. Furthermore, as Cummins (1984) emphasizes, BICS and CALP are not an exclusive of one another. Reducing them to such a

dichotomy oversimplifies the reality of language acquisition (Cummins, 1984). The ability to

engage simultaneously in both BICS and CALP, as fostered in STEM activities, complements

the development of proficiency in both linguistic fluencies. Zollman (2012) draws a parallel

between the needs of ELLs and STEM literacy and argues that "STEM literacy should not be

viewed as a content area but as a shifting didactic means (composed of skills, abilities, factual

knowledge, procedures, concepts and metacognitive capacities) to gain further learning (as cited

in Hoffman & Zollman, 2016, p. 84). Hoffman and Zollman (2016) provide a comparison of

STEM literacy and the needs of ELLs (Table 2).

Table 2

Comparing ELL Language Needs with STEM Literacy Needs.

English language learning needs	STEM literacy needs
Multiple opportunities to hear and use both social and academic English	Multiple opportunities to hear and use language to express STEM understandings
Rich contexts to help language comprehension, and the opportunity to engage and contribute to the interactive learning community	Rich contexts to help illustrate STEM concepts, and the opportunity to engage and contribute to the classroom STEM learning community
Instructional supports for written and spoken Language – e.g., intentional student grouping, multiple representations, scaffolding strategies for different tiers of English vocabulary	Appropriate supports for STEM concepts – e.g., hands-on student engagement, multiple representations, scaffolding strategies for STEM-specific vocabulary
Acceptance of "flawed" language for example non-standard English grammar in earlier stages of language learning	Acceptance of "flawed" language – for example, non-scientific language

Note. This table is reprinted from "What STEM teachers need to know and do for English language learners (ELLs): Using literacy to learn" by Lisa Hoffman and Allan Zollman (2016) in the Journal of STEM Teacher Education 51(1), p. 84 and is used in this thesis with permission from the authors.

In practice, STEM literacy and the supports needed for ELLs share commonalities. Framing

these requirements using theories from applied linguistics, such as CBI and hands-on activities,

highlights the potential for outreach programs to support the development of language alongside

STEM education.

2.5 Overlapping Content-Based Instruction with STEM Education

The use CBI is not a new model to support SLA. CBI encourages the concurrent teaching of language and academic content (Brinton, Snow & Weshche, 1989; Kaufman & Crandall, 2005), similar to conditions present when children learn their first language. It places the emphasis on meaning, rather than form (Krashen, 1981, 1989). The core of CBI is learning the language in a meaningful and useful context rather than for the sake of language development (Jakar, 2005). Unfortunately, many school-based models have repeatedly shown a discrepancy between the responsibilities of second language educators and content-based educators (Arkoudis, 2005; Tan, 2011), who often compartmentalize language and content learning. The literature notes the importance of fostering a professional interdisciplinary partnership in language and content learning to nurture L2 and content-based identities and engagement for ELLs. Such a partnership helps students to acquire both language and subject-based content (Arkoudis, 2005; Manitoba Ministry of Education, 2005; Navés, 2009; Kong & Hoare, 2011). Teachers need to scaffold learning in both areas for CBI to be effective (Lee, Quinn & Valdés, 2013).

It is not enough to place ELLs in a L2 literacy-based/ banking model classroom and expect spoken and written content transmission to automatically translate into "comprehensible input" (Krashen, 1983 as cited in Bilash, 2009). Furthermore, student engagement and motivation tend to decline when didactic teaching methods are used (Brown, Collins & Duguid, 1989). Although traditional textbook science education in schools is continually discouraged by students and educational researchers (Dewey, 2008; Imdieke, 2000; Wong, Pugh & Dewey Ideas Group at Michigan State University, 2001), the practice continues. The literature makes a clear distinction between the flaws of textbook/ lecture-based models and the benefits of an open-

ended inquiry used in CBI for science (Kessler & Quinn, 1987; McNay, 1985; Lee, Quinn & Valdés, 2013). The literature favors an inquiry-based model to support experimentation with science content and L2 skills (Kessler & Quinn, 1987). Dependence on didactic STEM teaching methods is usually reflective of teacher self-efficacy in STEM content (Morgan, 2015; Myszkal, 2016), as well as the disjointed understanding of the role of the English as a Second Language (ESL) educator versus the content-based educator (Arkoudis, 2005).

2.6 STEM Outreach Programs

The appreciation for the importance of connecting the community and industry professionals with the school is consistent across the academic literature, various policies, and pedagogical theory, including in the STEM disciplines (Fox, Sonnert & Nikiforova, 2009). Outreach programs provide a simple and practical liaison between industry and education. This connection offers students a visual representation of what the STEM workforce may resemble. Diversity in the STEM workforce is particularly important for students who are likely to be streamed in other directions during their school years, such as women, minorities and individuals with disabilities (Bailey & Alfonso, 2005; Bement, Lightfoot, Carlson, Frase, & Fresco, 2007; Espinosa 2011). Furthermore, outreach programs provide students with an alternative to traditional classroom pedagogies, with engagement at the forefront of their design (Kressly, 2009). This is in contrast to present day schooling, which is often driven by curriculums and high-stakes testing (e.g., the Education Quality Assurance Organization [EQAO] test) (Berliner, 2011).

According to Cannady, Greenwald, and Harris (2014) student interest in STEM by the end of grade 8 is pivotal to the STEM pathways typology which challenged the metaphor of the "leaky STEM pipeline" and proposed that attrition in STEM is not linear. Furthermore, using the

pipeline as a metaphor oversimplifies the issue because it indicates to policy makers that the solution is to merely "patch the holes" (p. 444). Rather, the authors suggest that individuals may leave and return to STEM during various stages of education. For example, while a student may leave STEM pathways for a non-STEM college diploma, they may change their mind and return to pursue a STEM degree later (Cannady, Greenwald & Harris, 2014). In order to foster this interest in STEM and allow the option of pursuing STEM degrees to remain open, Cannady, Greenwald, and Harris (2014) propose the following three measures to combat attrition in STEM: (a) positive attitude and interest in STEM subjects by grade eight (p. 447); (b) access to upper level secondary science and mathematics courses (p. 449); and (c) consideration of post-secondary STEM learning by grade twelve (p. 444). In relation to the first component, fostering positive attitudes and interest in STEM by grade eight, STEM outreach programs can nurture interest as they represent another avenue for teaching and learning science. These programs bring with them resources and equipment that students do not usually explore in their regular science, technology and mathematics classrooms (Kressly, 2009; Myszkal, 2016). These materials combined with open-ended, hands-on pedagogy creates a climate that fosters student inquiry (Bryan, Moore, Johnson & Roehrig, 2016). Although outreach programming in schools is not considered "informal science learning," which occurs outside of formal schooling on a voluntary basis, these programs are guided by the learners' needs and interests (Dierking, Falk, Rennie, Anderson & Ellenbogen, 2003) as the inquiry process in and of itself is student-driven (Edutopia, 2015). Informal science learning has been recognized for its potential to increase interest in STEM fields due to its capacity to foster curiosity and personal need to know (Falk & Dierking, 2010). Outreach programs also engage students through open-ended inquiry and accessible exploration of STEM content using hands-on manipulatives. The key characteristics that separate

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outreach programs from informal science learning are the pedagogies employed, specifically

scaffolding (Bouillion & Gomez, 2001; Venniz, den Brok & Taconis, 2017). Hence, outreach

can be considered an alternative form of science learning that can introduce students – including

ELLs – to STEM concepts in an open-ended model which fosters curiosity (Florence, DeCoito &

Gerrard, 2017; Venniz, den Brok & Taconis, 2017). These approaches become a springboard to

self-motivated learning, or rather, fostering positive attitudes and enhanced interest in STEM.

2.7 Addressing the Gaps in the Literature

The preceding review of the existing literature demonstrates that the field of STEM

education research in schools is still relatively new. Moreover, STEM education with ELLs is

only starting to emerge. From what is available in the literature, the focus is on making

connections from a theoretical perspective with empirical data supporting individual theories.

Thus, the pedagogical recommendations are being inferred. Nevertheless, the review of the

literature suggests that STEM outreach may have positive impacts on ELL pedagogies. However,

the literature fails to provide empirical longitudinal data with a focused analysis on ELL

students' experiences. The suggestions to support ELLs in STEM offered in the literature tend to

centre on academic success. Although pedagogical intervention by teachers to support student

success is foundational, the literature does not examine the affective domain, including attitude

and interest in STEM, as well as self-efficacy, while students are in the process of learning the

English language. As I discuss above, the STEM pathways typology (Cannady, Greenwald &

Harris, 2014) proposes that attitude and interest in STEM that students have developed by grade

eight is crucial. Moreover, both STEM education and applied linguistics refer to self-efficacy;

however, the literature has not combined these disciplines, and the studies do not unpack the

elements that support self-efficacy concurrently in SLA and STEM content knowledge. My

thesis fills this gap. Specifically, it examines the impact of STEM outreach workshops on a cohort of ELLs in terms of fostering positive attitudes and interest in STEM. Additionally, my thesis explores how collaborative classroom inquiry initiatives modelled by outreach programs support ELLs' self-efficacy in both STEM and SLA.

Chapter 3: Theoretical Framework

In my analysis of ELLs' attitudes, interest, and self-efficacy in STEM and SLA I use a theoretical framework that combines Situated Cognition Theory (SitCT) and Social Cognitive Theory (SocCT).

3.1 Situated Cognition Theory: The Integrated STEM Education Framework Modified for ELLs Attitudes and Interest in STEM

3.1.1 From situated cognition theory to an integrated STEM education framework.

Situated Cognition Theory (SitCT) is an epistemological theory that posits that authentic learning resides in the interrelationship between social, cultural, linguistic, and physical contexts (Brown, Collins & Duguid, 1989). In applying SitCT to STEM education, Kelley and Knowles (2016) have developed a framework for integrated STEM education (Figure 5).
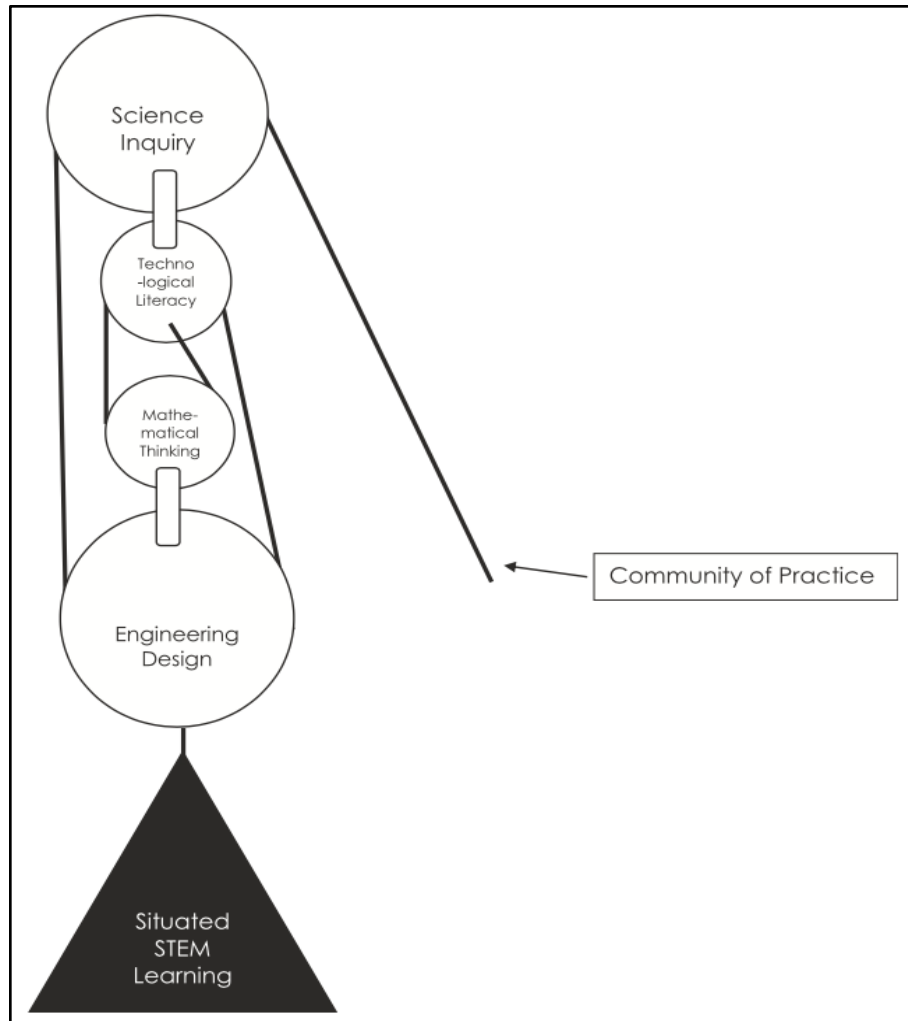
Figure 5. Graphic of the conceptual framework for STEM learning. Reprinted from "A conceptual framework for integrated STEM education" by T.R. Kelley and J.G. Knowles (2016) in the International Journal of STEM Education 3(11). Creative Commons license: http://creativecommons.org/licenses/by/4.0/.

Kelley and Knowles define integrated STEM education as "an approach to teaching the STEM content of two or more STEM domains, bound by practices within an authentic context for the purpose of connecting these subjects to enhance student learning" (2016, p. 3). This framework is supported by the following factors: (a) situated STEM learning; (b) engineering design; (c) science inquiry; (d) technological literacy; (e) mathematical thinking; and, (f) a community of practice (Kelley & Knowles, 2016, p. 4). The National Research Council (2014) suggests that

integration of these elements is fostered through "problem-, project-, or design-based tasks to engage students in addressing complex contexts that reflect real-world situations" (p. 51). In this thesis, I supplement the integrated STEM education framework with theories from applied linguistics and STEM education to support attitude and interest in STEM subjects. Furthermore, this framework is used to conceptualize the analysis of data from this case study adequately.

      3.1.2 Situated STEM learning. Situated STEM learning is the foundation, or the weight (see Figure 5), that bridges STEM concepts with active and applied STEM learning. Kelley and Knowles (2016) state that "when learning is grounded within a situated context, learning is authentic and relevant, therefore representative of an experience found in actual STEM practice" (p. 4). Situated STEM learning is inherently active as it uses hands-on learning experiences in a group/ social context to solve problems with a combination of STEM disciplines, reflective of real-world STEM experiences. The connection between STEM skills and the application of STEM literacy prompted the National Research Council (2009) to supplement the factors of SitCT. The NRC suggests that students should: (a) experience excitement, interest, and motivation to learn about phenomena in the natural and physical world and (b) think about themselves as science learners and develop an identity as someone who knows about, uses and sometimes contributes to science (as cited in NRC, 2014 p. 20). These additional factors highlight the importance of positive attitudes and interest in STEM content in developing an identity as a STEM participant. For ELLs, the development of identity and interest in STEM overlaps with situated language learning. That is, through situated STEM learning in an active problem-solving approach, ELLs are also situating their BICS and CALP proficiencies within a group of English speaking peers.

CBI aims to contextualize language in place of learning abstract linguistic rules. Brown, Collins, and Duguid (1989) use language development as an example of *situated knowledge and learning* in SitCT stating that,

> People generally learn words in the context of ordinary communication. This process is startlingly fast and successful … By contrast, learning words from abstract definitions and sentences take out of the context of normal use, the way vocabulary has often been taught, is slow and generally unsuccessful. (p. 32)

CBI claims that by contextualizing language and making it relevant to the subject matter, as well as to ELLs' real-world experiences, ELLs will be motivated to acquire language to support both their linguistic and content learning needs (Valentine & Repath-Martos, 1992). In STEM education, this means ELLs are not only developing their CALP in STEM, but, given the emphasis on activities in group-work contexts as the foundation for SitCT, their BICS proficiency advances as well. These experiences support the development of STEM identities, and motivates learners. Therefore, it influences ELLs' attitude towards and interest in STEM content and self-efficacy in both STEM and SLA.

3.1.3 Engineering design. The first pulley within the integrated STEM education framework focuses on the design process through engineering (Figure 5). Kelley and Knowles (2016) argue that:

> The very nature of engineering design provides students with a systematic approach to problem-solving that often occur naturally in all of the STEM fields. Engineering design

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provides the opportunity to locate the intersections and build connections among the

STEM disciplines which have been identified as key to subject integration. (p. 5)

The engineering component of the integrated STEM framework is directly related to active

learning within SitCT, as well as to real-world problem solving (Brown, Collins & Duiguid,

1989). In addition to supporting STEM learning, the design process fosters creativity, which

encourages interest in STEM subjects. Brown, Collins, and Duiguid (1989) adopt a constructivist

paradigm to frame the design process. They argue that engaging in opportunities to build on

students' own experiences and knowledge through design and scientific investigation "enhances

their understanding of science – and, for many, their interest in science – as they recognize the

interplay among science, engineering, and technology" (p. 12 as cited in Kelley & Knowles,

2016, p. 5). This emphasis on interest in science – and subsequently, STEM content – through

the design process is essential as it probes students' creativity and fosters autonomy through

hands-on activities.

Project Zero – a research initiative at Harvard Graduate School of Education (2015) --

refers to the relationship between autonomy and design as *agency by design* and *maker*

empowerment. The concept of *maker empowerment* refers to: "a sensitivity to the designed

dimension of objects and systems, along with the inclination and capacity to shape one's world

through building, tinkering, re/designing, or hacking" (Agency by Design, 2015, p. 5). The

objective of maker *empowerment* and *maker centered-learning* is rooted in fostering a distinct

mindset that provides students with a dispositional outcome – this disposition is considered

agency by design (Agency by Design, 2016). Agency by Design frames the maker mindset

within the following four P's: (a) people; (b) personalization; (c) persistence; and (d) play

(Maslyk, 2016, p. 13). The social context of learning, including problem-solving in a group

context through creative activities, underscores that students' agency enhances when they can

create and make within scientific inquiry and design. The NRC (2014) states that "engineering

design can be a highly social and collaborative enterprise as well. Engineers engaged in design

activities often work in teams and communicate with clients and others" (p. 45). These

components can potentially shape attitudes towards and interest in STEM (NRC, 2014).

  3.1.4 Scientific inquiry. The second pulley in the conceptual framework for STEM

learning (Figure 5) explores the relationship between engineering design and scientific inquiry.

According to Chiappetta (2004), scientific inquiry is "used to promote activity-oriented learning

that reflects scientific investigation, specifically the observation, experimentation and reasoning

used by scientists" (p. 46). Much of the literature stresses that science is a process of inquiry and

investigation from which children learn through activity (Counsell et al., 2016; Doris, 2010;

NRC, 2014). In their discussion of fostering scientific inquiry within the integrated STEM

education framework, Kelley and Knowles explicitly differentiate between lab experimentation

and minds-on learning. They state that "students can become drivers of their learning when given

the opportunity to construct their own questions related to the science content they are

investigating (2016, p. 5). According to Chiapetta and Adams (2004), scientific inquiry should

promote:

- understanding of fundamental facts, concepts, principles, laws, and theories;
- development of skills that enhance the acquisition of knowledge and understanding of natural phenomenon;
- cultivation of the disposition to find answers to questions and to question the truthfulness of statements about the natural world;

- formation of positive attitudes towards science; and

- acquisition of understanding about the nature of science (p. 47).

Therefore, the relationship between engineering design and scientific inquiry aims to enhance positive attitudes and interest as well as engagement in STEM content through discovery and design.

 3.1.5 Technological literacy and mathematical thinking. Technological literacy and mathematical thinking are depicted as two smaller pulleys between engineering design and science inquiry within the integrated STEM education framework (Figure 5). Both are considered tools to support inquiry and design. These elements design and create the integrative and interdisciplinary approach to fostering the integrative STEM education framework. Fortier et al. (1998) define technological literacy as:

> [T]he ability of an individual, working independently or with others, to use tools, resources, processes, and systems responsibly to access and evaluate information in any medium, and to use that information to solve problems, communicate clearly, make informed decisions, and construct new knowledge, products, or systems. (p. 1)

Kelley and Knowles (2016) suggest that there are two views of technology – that is, the engineering view and the humanities view. The engineering approach proposes that technology is "equated with the making and using of material objects" (Micham, 1994, p. 128 as cited in Kelley & Knowles, 2016, p. 6). The engineering design process emphasizes design while technology considers the process of implementing and creating these designs. In this sense, technology becomes a tool for creating and, therefore, learning. Brown, Collins, and Duguid (1989) highlight the importance of tools for learning when they state that "people use tools

actively rather than just acquire them, by contrast, build an increasingly rich implicit understanding of the world in which they use the tools and of the tools themselves" (p. 33). This conception of technology links engineering design and scientific inquiry to create a functional product and express student competence in the subjects (NRC, 2014). The humanities perspective on technology equates technology with "a response for specific human endeavor" (Kelley & Knowles, 2016, p. 6). This perspective embodies the notion of learning and enculturation within the SitCT epistemology. More specifically, it considers technology to be "more than a sum of tools, instruments, artifacts, processes, and systems … [technology] influences the structure of the cultural/ social order regardless of its user intentions … [and serves] human values and influence[s] value formation" (Kelley & Knowles, 2016). Common to these two viewpoints are process, tools, and society (Kranzberg, 1987).

Mathematical thinking is also a mechanism supporting scientific inquiry and engineering design; however, it is important to emphasize that not all mathematical concepts apply to engineering design (Kelley & Knowles, 2016). The integrated STEM education framework highlights that interest in mathematics goes up when the content is applied to real-life contexts (Kelley & Knowles, 2016). Williams (2007) states that "contextual teaching can give meaning to mathematics because students want to know not only how to complete a mathematical task but also why they need to learn the mathematics in the first place. They want to know how mathematics is relevant to their lives" (as cited in Kelley & Knowles, 2016, p. 7). Renniger (2010) points out that there are two phases in triggering interest. The early stage needs "real world connections and connections to prior experiences and instruction" (as cited in NRC, 2014, p. 95). Thus, mathematical thinking needs to be applied within an interdisciplinary paradigm, while relating personally to students to foster interest.

3.1.6 A community of practice. Represented as the rope connecting the pulley system, a community of practice refers to the social components of SitCT. The salient features of group learning within SitCT are: (a) collective problem-solving; (b) displaying multiple roles; (c) confronting ineffective strategies and misconceptions; and (d) providing collaborative work skills (Brown, Collins & Duguid, 1989, p. 40). Kelley and Knowles frame group learning within a community of STEM learning. In this thesis, the community for ELLs is comprised of English speaking STEM learners that concurrently support language and STEM content acquisition. Brown, Collins, and Duguid explain in situating enculturation within SitCT that,

> From a very early age and through their lives, people consciously or unconsciously adopt the behavior and belief systems of new social groups. Given the chance to observe and practice *in situ* the behavior of members of a culture, people pick up relevant jargon, imitate behavior and gradually start to act in accordance with its norms. (1989, p. 34)

For ELLs, the jargon refers to their BICS and CALP proficiencies. Furthermore, working within a group context in STEM allows for negotiation and scaffolding through the navigation of various roles in a communal context. ELLs can seek language support when needed as well as assistance in STEM education.

Kelley and Knowles (2016) also suggest that the benefits of forming a community of practice include "opportunit[ies] to engage local community experts as STEM partners such as practicing scientists, engineers, and technologists who can help focus the learning around real-life STEM contexts regardless of pedagogical approach" (p. 7). This community and school connection proves the foundation for this thesis in terms of engaging ELLs with STEM professionals through STOp. ELLs can not only learn from their peers who share the process of

acquiring knowledge, but gain access to STEM in real-life contexts, and associated careers. Barron et al. (2009) support attitude and interest in STEM education through interactions with others. They argue that, "educators, workshop facilitators, peers provide models of how one engages with others and works on the problem solving of STEM content. They can be a source of encouragement, stimulating feelings, competence, and continued engagement" (as cited in NRC, 2014, p. 94). This key feature in STOp workshops supports students by exposing them to industry and bridging real-life context, thus potentially increasing interest and positive attitudes towards STEM.

3.2 Social Cognitive Theory: Developing and Supporting Self-Efficacy in STEM and SLA

The research (Willis, 2007; Park, 2014) on emotion and cognition indicates that there is a connection between these areas of development. Specifically, to support success in learning, attention needs to be directed towards the emotional state of the learner as much as cognitive stimulation (Park, 2014). Founded in psychology and central to SocCT (Simon et al., 2015), self-efficacy (Bandura, 1982) is a concept used to denote the difference between performance outcome expectations and personal perceptions in the ability to carry out behaviours to accomplish a task successfully. Bandura (1982) defines his theory of self-efficacy as "judgments of how well one can execute courses of action required to deal with prospective situations" (p. 122). In terms of SLA and STEM self-efficacy, the language barrier affects various sources of self-efficacy as ELLs try to navigate both language and STEM content. Specifically, if ELLs feel that their language gets in the way of acquiring STEM content knowledge, then they are less likely to perform and sustain through challenging learning experiences in both STEM and language learning. Bandura (1977) explains that "efficacy expectations are a major determinant

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of people's choice of activities, how much effort they will expend, and of how long they will sustain effort in dealing with stressful situations" (p. 194). For STEM education, the STEM pathways typology highlights the importance of supporting a positive attitude towards and interest in STEM by grade eight (Cannady, Greenwald & Harris, 2014, p. 444). Thus, if a student feels that they do not have the ability to execute STEM skills successfully, it is challenging for them to form a positive attitude and interest in STEM subjects (Simon et al., 2015, p. 6). Moreover, if a student feels they do not have the skills to effectively use the English language, they will likely remove themselves from situations where they use the language extensively to successfully accomplish a task (Krashen, 1982). This includes STEM learning experiences. My thesis considers self-efficacy with both STEM and SLA. I argue that when ELLs' self-efficacy is supported, these students can have their learning scaffolded in STEM pathways while also promoting language learning. ELLs are then motivated to sustain through STEM and language tasks more efficiently and are less likely to become streamlined in alternative learning directions. Bandura's (1977) self-efficacy theory considers four sources of efficacy, including: (a) performance accomplishments; (b) vicarious experiences; (c) verbal persuasion; and (d) emotional arousal (p. 195). Each of these in combination supports various efficacy outcomes – both positive and negative. While some of the sources of efficacy are stronger than others, positive learning experiences that consider and foster self-efficacy for learners needing language assistance can support ELLs while they are moving through the stages of language acquisition. As a result, these students are not losing the opportunity to be multilingual STEM literate citizens during the imperative middle school years.

3.2.1 Performance accomplishments. Performance accomplishments in Bandura's theory of self-efficacy are considered one of the most influential sources. Bandura stresses the

influence of performance experiences relative to personal mastery experiences. He suggests that "successes raise mastery expectations; repeated failures lower them, particularly if the mishaps occur early in the course of events" (Bandura, 1977, p. 195). In STEM education, a variety of studies have associated mastery goals as a predictor of positive emotions and positive self-efficacy in STEM (Daniels et al., 2008; Pekrun, Elliot & Maier, 2009; Simon et al., 2015). For ELLs, hands-on learning is less dependent on mastery of language and, therefore, eases the burden of the language barrier (Frank, 2011, Lee et al., 2008; Shanahan, Pedretti, DeCoito & Baker, 2011;). As thinking is not bound to one language, through hands-on learning ELLs gain control of how they interact with STEM (Frank, 2011). This model allows students to develop interest in the topic. Furthermore, for ELLs, experiences that help students to explore their thought processes can enhance their self-efficacy both in SLA and in subject matter by providing opportunities for them to express their thoughts and articulation at their own pace (Lewis et al., 2011).

3.2.2 Vicarious experience. Vicarious experience pairs with performance accomplishments in that individuals do not rely solely on mastery experiences. Bandura (1977) states that "seeing others perform threatening activities without adverse consequences can generate expectations in observers that they too will improve if they intensify and persist in their efforts" (p. 197). While hands-on activities and the workshop model are not threatening per say, some students may feel that their language abilities are not suited to STEM learning and at first find some exercises challenging. However, for ELLs, vicarious experience as a source of self-efficacy highlights the importance of collaborating with peers. When they participate in hands-on STEM workshops that centre on group work, ELLs can watch and collaborate with students who have similar characteristics / life experiences (e.g., gender, age, language, ethnicity, etc.) while

they engage in STEM learning. In its pure definition, vicarious experiences refer more specifically to the subject as an onlooker without interaction (Bandura, 1982). However, within the workshop model, which emphasizes hands-on learning, STOp also uses hands-on demonstrations where ELLs can observe their peers as they participate in an activity exploring the workshop's STEM topic. Resources exploring how to support English language learners in their core education recommend the use of props and demonstrations to convey language understanding (Park, 2014). These recommendations generally use the teacher as the provider of the demonstration; however, STOp aims to incorporate students through testing designs and exploring theories and concepts. This approach supports ELLs' self-efficacy both in STEM and in language because ELLs can watch as their peers interact with varied subject matter safely. The combination of vicarious experiences and performance accomplishments can foster self-efficacy in STEM and SLA on a multitude of levels for ELLs, which is distinct from traditional science education.

3.2.3 Verbal persuasion. The impact of verbal persuasion is not high in comparison to performance accomplishments and vicarious experiences; however, this source highlights how external influencers can support self-efficacy (Bandura, 1977). The formal definition of verbal persuasion states that "people are led through suggestion into believing they can cope successfully with what has overwhelmed them in the past" (Bandura, 1977, p. 198). Bandura emphasizes that mastery experiences developed strictly through verbal persuasion "can be readily extinguished by disconfirming experiences" (1977, p. 198). In the context of the workshop model, Vygotsky (1978) considers the zone of proximal development under the notion of scaffolding. In STOp workshops, this is associated with the role of adults as facilitators of learning (e.g., teachers and STEM professionals). While it is not enough to solely tell ELLs that

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they are capable, the workshop model encourages reinforcement and constructive interaction and feedback from peers, teachers and workshop facilitators. This is instrumental in scaffolding students to acquire STEM content knowledge as well as informal language experiences.

3.2.4 Emotional arousal. This source of efficacy refers to the emotional responses to learning. According to Bandura (1977):

> Stressful and taxing situations generally elicit emotional arousal that, depending on the circumstances, might have informative value concerning personal competency … People rely partly on their state of physiological arousal in judging their anxiety and vulnerability to stress. Because high arousal usually debilitates performance, individuals are more likely to expect success when they are not beset by aversive arousal than if they are tense and viscerally agitated. (p. 198)

Thus, if the learning experience triggers an anxiety response, the learner's self-efficacy will be low. As a result, the student is less likely to perform successfully. For language learners, emotional arousal impacts their ability to use and acquire language. In applied linguistics, this is referred to as *Affective Filter Hypothesis*, which Krashen (1985) defines as:

> A mental block that prevents acquirers from fully utilizing the comprehensible input they receive for language acquisition. When it is 'up', the acquirer may understand what he hears and reads, but the input will not reach the [language acquisition device]. This occurs when the acquirer is unmotivated, lacking in self-confidence, or anxious … The filter is down when the acquirer is not concerned with the possibility of failure in

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language acquisition and when he considered himself to be a potential member of the

group speaking the target language. (p. 81)

If there is an emotional response to learning content – including STEM – then the learner is less likely to put him/ herself in a vulnerable position (Simon et al., 2015). A variety of research findings shows that one of the leading causes of attrition from STEM pathways is emotional rather than academic (Simon et al., 2015). For students with diverse learning needs, the relationship between their learning needs and hindrances, along with their emotional responses, directly impacts learning. For ELLs, this relationship takes the form of the language barrier. If ELLs feel they need to use the language to be successful in communicating their understanding of STEM while their language skills are still developing – despite their funds of knowledge in STEM and knowledge acquired in their L1 – this can lead to emotional arousal which in turn, can affect their self-efficacy both in STEM and in SLA. However, when self-efficacy is considered and supported through open-learning pedagogies, then ELLs' attitudes towards and interest and self-efficacy in STEM can be fostered while students are also trying to acquire a language. As a result, ELLs can envision themselves as STEM participants. This increases the likelihood of ELLs pursuing STEM pathways and decreases potential attrition in this diverse learning group.

Chapter 4: Methodology

As I have mentioned above, this research is part of a larger longitudinal mixed-methods (Mills, Durepos & Wiebe, 2010) study that involves the partnership between four STEM stakeholders: an outreach program, a university, a school board, and an industry partner (DeCoito, 2015). This thesis analyses the data on students identified as ELLs that was collected for the larger study. This "cohort analysis" takes the form of a case study (Cohen, Manion & Morrison, 2011) and investigates a subset of data associated with students who have been classified by their school as needing "English as a second language intervention". This chapter details the methodologies employed in the thesis.

4.1 Methods

4.1.1 Research Design. The larger longitudinal study relies on a mixed-methods design or, more specifically, a sequential explanatory design. This design is characterized by the collection and analysis of survey data followed by a collection and analysis of open-ended responses, reflections, and interview data. The purpose of this approach is to use qualitative results to assist in explaining and interpreting quantitative results (Creswell, 2015).

4.1.2 Why mixed methods? Mixed methods research has been defined as a "third paradigm" in recent years (Cohen, Manion & Morrison, 2001; Johnson & Onwuegbuzie, 2004; Teddlie & Tashakkori, 2009). Several scholars claim that both qualitative and quantitative data can complement one another (Ercikan & Roth, 2006). Cohen, Manion and Morrison (2011) argue that:

Mixed methods research recognizes and works with, the fact that the world is not exclusively quantitative or qualitative; it is not an either/or world, but a mixed world,

even though a researcher may find that the research has a predominant disposition to, or

requirement for, numbers or qualitative data. (p.22)

For these authors, mixed methods research addresses both the 'what' (numerical and qualitative

data) and 'how or why' (qualitative) types of research questions. My study employs an

integrated mixed design, wherein "mixed methods are used at each and all stages (perhaps

iteratively: where one stage influences the next) and levels of research" (Teddlie & Tashakkori,

2009 as cited in Cohen, Manion & Morrison, 2011, p. 25). I adopt this approach to data

collection and analysis in order to explore attitude towards and interest in STEM as well as self-

efficacy using both qualitative (open-ended questions and workshop observations) and

quantitative measures (S-STEM survey). These measures support the design the interview

protocol that involves corroboratory and complementarity strategies to further explore the

experiences of ELLs who have participated in STOp workshops. The strength of a mixed

methods approach is often accredited with: (a) data triangulation (Teddlie & Tashakkori, 2009);

(b) compensation (Johnson & Onwuegbuzie, 2004; Najmaei, 2016); and, (c) complementarity

and corroboration (Johnson & Onwuegbuzie, 2004; Cohen, 1977).

Triangulation is one of the key validity measures in mixed methods research (Teddlie &

Tashakkori, 2009). It rests upon the assumption that two more facets within the research process

strengthen the reliability of the study (Thurmond, 2001). This thesis relies on data triangulation

(Teddlie & Tashkkori, 2009) through the use of multiple quantitative and qualitative methods to

ensure the validity of the findings.

Another benefit of using mixed methods in research is that the strengths of one method

can be used to overcome the weaknesses of another (Johnson & Onwuegbuzie, 2004). This is

known as *"compensation"* (Najmaei, 2016). Johnson and Onwuegbuzie (2004) break down the strengths and weaknesses of qualitative, quantitative, and mixed methods research to illustrate how one method can compensate for another. For example, a weakness of quantitative research is that "knowledge produced may be too abstract and general for direct application to specific local situations, context, and individuals" (p. 19). However, a strength of qualitative is that "qualitative approaches are responsive to local situations, conditions and stakeholders needs" (p. 20). At the same time, a weakness of qualitative data is that "the results are more easily influenced by the researcher's personal biases and idiosyncrasies" (p. 20). With quantitative methods, "the research results are relatively independent of the researcher" (p. 19). In this study, I employ data collection tools that build on one another to show breadth and depth of the experiences ELLs had with STOP. The post S-STEM survey asks participants to rate on a 5-point Likert scale how much they agree with the following statement: "*I enjoy learning science, technology, engineering and/or math with [STOp]"*. Later in the post S-STEM survey, there are a series of open-ended questions which ask students: *"What do you think was the most exciting about [STOp] workshops?"* and, "*What could [STOp] do to improve their workshops?*" The scale elicits responses from participants that explore how they felt about participating in the workshops. The open-ended questions explore why the students felt that way.

Complementarity refers to how "the phenomenon and/or relationships is developed by combining the findings," while corroboration denotes "the credibility of inferences from one method is assessed by another" (Tashakkori & Teddlie, 2008 as cited in Najmaei, 2016, p. 27). Due to the nature of my research design, I use both complementarity and corroboration to explore findings in greater depth. These two strengths build triangulation to confirm the investigated phenomenon. I also used corroboration and complementarity in the process of

designing the interview protocol. For instance, an example of corroboration in the S-STEM survey are the open-ended questions asking students, *"What do you think is most exciting about [STOp] workshops?"* and *"What could [STOp] do to improve their workshops?"* These questions are asked again in the interview protocol (Appendix B) to explore overlap and confirm the validity of the thematic analysis that emerged in interpreting the open-ended questions across three years. An example of complementarity is my comparison of the 5-point Likert scale questions from the S-STEM survey with the interview protocol. The S-STEM survey is designed for all middle school students, while the interview protocol was modified to explore the impact of the workshops on those identified as ELLs. In the S-STEM survey, students rate their feelings towards the statement *"I am confident when I do science"*. During the interview, ELLs are asked *"How did you feel when you were doing the workshops (e.g., confidence, ability, self-efficacy)?"* The goal of this approach is to expand on the impact of the workshops on ELLs' attitudes, interests, self-efficacy and language development.

4.1.3 Why a longitudinal case study? Longitudinal studies are "studies that are conducted over an extended period of time" (Cohen, Manion & Morrison, 2011, p. 266). My research could be described as longitudinal because it uses repeated measures to document experiences over time. The data illustrates participants' language development while engaging with the workshops, as well as the interplay between the two to illustrate change over time.

This thesis includes analysis of data drawn from a larger longitudinal study that I participated in as a research assistant. During Phase III of the study, a case study of ELLs was created for the purpose of my thesis. Hence, I conducted a secondary analysis on data collected from ELL participants, specifically, from the S-STEM survey, workshop observations, open-ended questions, as well as primary interview data. A strength of using a case study is that the

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case has a context. Cohen, Manion, and Morrison (2009) state that "context is a powerful determinant of both causes and effects, and in-depth understanding is required to do justice to a case" (p.289). As indicated in chapter three, this study uses SitCT as a theoretical framework which asserts that learning is contextual from a variety of social and active influencers. Case studies explore context in detail. Recognizably, there is a possibility of generalization within a case study – that is, the experiences of one case are not necessarily applicable to another group within a different context. This study examines the experiences of one group of ELLs and contributes to the limited literature exploring this phenomenon. There are a variety of strengths associated with both longitudinal and case studies, thus making it the most appropriate approach for this thesis.

 4.1.4 Recruitment and Participants. This case study examines the attitudes towards and interests in STEM, as well as the development of self-efficacy in both STEM and SLA, of a group of 13 ELLs who participated in STOp workshops during their middle school years. According to the Supporting English Language Learners (2008) resource guide, school policies specify that ELLs receive academic support from an ESL qualified, Ontario certified teacher (Ontario Ministry of Education, 2001). The school principal and an ESL teacher at Trillium Street Middle School identified case study participants who were pre-assessed at stages one and two. The Ontario Ministry of Education (2001) understands stage one and two as:

1. *Using English for Survival Purposes:* Students at Stage 1 are becoming familiar with the sounds, rhythms, and patterns of English ... Their understanding depends on visual aids. They often respond non-verbally or with single words or short phrases.

2. *Using English in Supported and Familiar Activities and Contexts:* Students at Stage 2 listen with greater understanding and use everyday expressions independently… and use personally relevant language appropriately (p. 9).

Although the larger project included four schools, this case study focuses on one school *Trillium Street Middle School*. Trillium Street Middle School was selected for the following reasons: (a) the school has a high level of ELL enrollment; (b) in response, the school established an English as a Second Language intervention program with a team of three ESL certified teachers; and (c) The ESL teachers were keen to integrate their students in STOp workshops. Inclusion criteria was comprised of ELLs at stages 1 or 2 who participated in at least four workshops. These students were invited to participate in an interview. It is important to note that due to the language barrier and limitations in collecting the data, some participants participated only in the interview or only in the surveys/ open-ended questions, and therefore, have some unknown components. Table 3 illustrates a profile of each of the 13 ELL participants.

Table 3

Case Study Participant Backgrounds (n=13)

Name	Gender	L1	Stage	Spoken at home	L2 parents	Homework support	***Strategies
Salim	M	Malayalam	2	Malayalam	Yes	Parents	T, Em & Ep
Tarik**	M	Arabic	1	Arabic	Limited	Independent	N/A
Eesha**	F	Arabic	1	Arabic	Mom Only	Mom	T & Ep
Malik	M	Arabic	2	Arabic	Limited	Older Sister, Mom (sometimes)	T, Ep, Helps w/ Math
Ibrahim	M	Arabic	2	Arabic	Mom Only	Older Brother	Em & Ep
Sabir**	M	Arabic	2	Arabic	None	Brother, Friends	T
Cantara	F	Arabic	2	Arabic	Mom Only	Mom	Ep
Octavia	F	Vietnamese	Fluent	Vietnamese & English	All Fluent	Tutoring	N/A
Omar*	M	Arabic	2	Unknown	Unknown	Unknown	Unknown
Lufti*	M	Arabic	1	Unknown	Unknown	Unknown	Unknown
Yasin*	M	Arabic	2	Unknown	Unknown	Unknown	Unknown
Eisa*	M	Arabic	2	Unknown	Unknown	Unknown	Unknown
Adya*	F	Unknown	1	Unknown	Unknown	Unknown	Unknown

Note. * No Interview; ** Interview Only (Incomplete S-STEM Participation). *** T = Translate; Em= Provides Examples; Ep = Explains; N/A = Not Applicable.

4.1.5 Phases of data collection. This case study draws on data from a group of ELLs from Trillium Street Middle School. Each Phase has a quantitative and qualitative component in addition to the use of repeated measures for assessing the impact of the STEM workshops on the ELL cohort over time. The data collection followed the same process in Phases I, II, and III, with pre-surveys administered at the beginning of the school year, followed by two STEM workshops, and post-surveys administered at the end of the school year. Figure 6 a, b, and c illustrates the procedure for data collection.

Phase I. In the fall of 2013, the ELLs were in grade 6. Surveys were administered at the time and served as baseline data for the longitudinal study. The ELL students then participated in two STEM workshops exploring electricity and electrical devices and space. In the electricity workshop, ELLs made circuits, discussed magnetism with positive and negative charges, and did an activity exploring static electricity using balloons. For the space workshop, students created the Canada Arm 1 End Effector using disposable cups and string. They practiced lifting items like chairs as a team, explored planets, and participated in challenges that simulated life in space such as having to write using a large "space" glove. Distribution of the post S-STEM survey occurred in May 2014 and included open-ended questions to explore students' experiences in detail.

Phase II. The case study group was in grade 7 in Phase II, during which they participated in two additional STEM workshops. In these workshops, the ELLs explored structures as well as substances and mixtures. In the structures workshop, ELLs learned about engineering careers, built a cantilever, created a bridge from newspaper, and tested the structures using weights. The substances and mixtures workshop allowed students to become chemists while they investigated the properties of substances and mixtures, explored the Tyndall effect and ways to clean up oil spills in an environmentally friendly manner. The post S-STEM survey was administered in May 2015.

Phase III. In Phase III, the ELLs case group was in grade 8 and engaged in two STOp workshops that explored fluids and mechanical systems. In the fluids workshop, ELLs learned about pneumatic and hydraulic systems through activities building various hydraulic models such as a forklift and a robotic arm from syringes and tubes. For the systems workshop, some activities that the case study explored included creating simple machines like pulley systems and

moving loads, while making use of mechanical advantage. The workshop concluded with an activity where the students created a complex system that had to overcome obstacles in a mock disaster relief scenario. In May of 2016, the students completed the post S-STEM survey. At the end of Phase III, ELLs were invited to participate in an interview in orer to reflect on their experiences as ELLs and STEM learners.

Sept 2013	Oct 2013	Nov 2013	Dec 2013	Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	Jun 2014
Case study participants begin grade 6	S-STEM Survey **Baseline data**	*Intervention* 2 STOp workshops administered "Understanding matter and energy – electricity & electrical devices" workshop "Understanding earth and space systems – space" workshop						S-STEM Suvey	
		STOp workshop observations						Open-ended questions	

a) Phase I (2013-2014)

Sept 2014	Oct 2014	Nov 2014	Dec 2014	Jan 2015	Feb 2015	Mar 2015	Apr 2015	May 2015	Jun 2015
Case study participants begin grade 7	S-STEM Survey	*Intervention* 2 STOp workshops administered "Understanding structures and mechanisms – form & function" workshop "Understanding matter and energy – pure substances and mixtures" workshop						S-STEM Suvey	
		STOp workshop observations						Open-ended questions	

b) Phase II (2014-2015)

Sept 2015	Oct 2015	Nov 2015	Dec 2015	Jan 2016	Feb 2016	Mar 2016	Apr 2016	May 2016	Jun 2016
Case study participants begin grade 8	S-STEM Survey	*Intervention* 2 STOp workshops administered "Understanding matter and energy – fluids" workshop "Understanding structures and mechanisms – systems in action" workshop						S-STEM Suvey	Case study participants proceed to secondary school
		STOp workshop observations						Open-ended questions	

c) Phase III (2015-2016)

Figure 6. Data collection timeline.

4.1.6. Data collection tools. My research uses a variety of quantitative and qualitative tools to facilitate the data collection process. This section details each of the tools. I explain how the tools were used, any validation measures, and the rationale for the use of these instruments.

1. The S-STEM survey and open-ended questions. The S-STEM survey is a tool created by the Friday Institute for Educational Innovation and validated for reliability by the National Science Foundation (Erkut & Marx, 2005). The S-STEM survey uses a series of 5-point

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Likert scales probing middle school students' attitudes, interests, self-efficacy, and career aspirations within science, technology, engineering and mathematics, and 21st century learning skills (Figure 7).

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
18. I like to imagine creating new products.	O	O	O	O	O

Figure 7. Sample S-STEM survey statement from Engineering and Technology scale

The final portion of the S-STEM pre-survey explores students' perceptions of their anticipated academic performance in science, mathematics, and language arts, post-secondary routes (e.g., college, university, etc.), and relationships with adults in STEM careers. The post S-STEM survey has an additional section that focuses on student critique of engagement and experience with STOp workshops, their interest in STEM careers, and critique of their choice to pursue (or not) a STEM career by influences such as teachers, family members, and extracurricular activities. During Phase I and II, the open-ended questions in the post S-STEM survey included the following: "*Have [STOp] workshops encouraged you to be interested in science, technology, engineering and/or math either in school or outside of school? If so, how?*" Given that some participants did not feel that the workshops had that impact, this question was modified in Phase III to explore the reasons why. In Phase III, this question asked: "*Have [STOp] encouraged you to be interest in (a) science – [yes] [no]; (b) technology – [yes] [no]; (c) engineering – [yes] [no]; and (d) math – [yes] [no]*" followed by two questions: "*If you chose one or more of the above subject, how did the workshop encourage you to be interested?*" OR "*If you did not choose any of the above subjects, explain why?*" The modification probed the impact of STOp, and both positive and negative responses in detail. The case study participants completed in the

S-STEM survey in their homeroom classrooms; however, the option to have a bilingual peer or ESL teacher transcribe their responses was provided. Those who transcribed were asked to translate the statements and not engage in reciprocal conversations that could influence the results of the survey.

      2. Workshop observations. When participating in the workshops, ELLs integrated with their homeroom. A protocol was designed by the principal investigator, Dr. Isha DeCoito, focusing specifically on the interactions between workshop facilitators, educators, and students (Appendix A). The protocol highlights student interactions. It records specific occurances such as language learners, gender, and ability and their interactions with peers, educators and the workshop facilitators. Observations by research assistants used an "observer-as-participant" method. Frequently, the workshop facilitator or classroom teacher introduced observers to students, and students occasionally interacted with the research assistants (Cohen, Manion & Morrison, 2011). Interactions between the research assistants and the students and/or teachers were initiated by the participants rather than the members of the research team to preserve the role of observer. Observations taken by research assistants, in the role of observers took note of facts, events, and behaviours as they occurred (Cohen, Manion & Morrison, 2011), while students, teachers, and workshop facilitators engaged in STOp workshops. Observations placed emphasis on the physical (e.g., workshop environment set up, etc.), human (e.g., organization of student groups, etc.), interaction (e.g., formal, informal, planned, verbal and nonverbal interactions between students, workshop facilitators and teachers, etc.), and program characteristics (e.g., pedagogies, program organization, etc.) (Cohen, Manion & Morrison, 2011). Additionally, videos and photographs were taken during the workshop observations to provide audio and visual supplementation. The videos recorded actions and audible

conversations as students engaged with different components of the workshop; thus, they provide context to the learning and responses to the process (Cohen, Manion & Morrison, 2011).

3. Interviews. ELL participants were invited to voluntarily participate in an open-ended interview (Cohen, Manion & Morrison, 2011) at the end of Phase III. Interview questions probed students' experiences, perceptions, and engagement with STEM and STOp as both a STEM learner and ELL. From the position of an ELL, the interviewees elaborated on their experiences from their standpoint. They discussed how the workshops helped them to develop their language, conversations, and/or STEM learning. The interview protocol (Appendix B) was modified from Dr. Isha DeCoito's original protocol in order to explore the role of the ELLs and their participation in the workshops. Given the ELLs communication needs, the questions were designed to be concise and allow for alternative forms of communication to supplement responses. For example, question 9 asks: "Did you learn any new science, technology, engineering and/or math words during the workshops? Which ones? Can you tell me what they mean? ***Offer a paper to the students so they can draw to communicate**"*.This question reflects the expectation that there might have been some difficulty in explaining multi-level questions. When the interviews were conducted, this question was asked one part at a time to allow for processing and making additional resources available. ELLs had extra time during the interview, which resulted in long pauses within the interview transcripts. The goal was to allow for the ELLs to communicate to the best of their ability without being influenced by examples or prompts unless they asked for clarification. During the interviews, the school had records of the interviewees' bilingual peers who spoke the same language as them. These peers were asked to support the interviews when the language barrier made it difficult for the interviewee to express themselves. Peer translators were instructed not to engage in reciprocal conversations and only to

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translate in order to preserve the validity of interview data as accurate representations of ELLs' individual experiences.

4.2 Data Sources

Thirteen ELLs participated in various components of data collection. During Phase I, the participation was lower due to the language barrier as well as tracking where the student was at the time. Due to the need for ESL intervention, occasionally the participants were in another class. Given that a team of research assistants collected data, these students may have been missed or absent during data collection. This section will showcase participation and provide a summary of the case study across the three Phases (Table 4).

Table 4

Case Study Participation in Data Collection (n=13).

Name	Phase I			Phase II			Phase III			
	Pre- S-STEM	Post S-STEM	Open-Ended Questions	Pre- S-STEM	Post S-STEM	Open-Ended Questions	Pre- S-STEM	Post S-STEM	Open-Ended Questions	Interviews
Salim	N	N	N	Y	Y	Y	Y	Y	Y	Y
Tarik	N	N	N	N	N	N	N	N	N	Y
Eesha	N	N	N	N	N	N	N	N	N	Y
Malik	N	N	N	Y	Y	Y	Y	Y	Y	Y
Ibrahim	N	N	N	Y	Y	Y	Y	Y	Y	Y
Sabir	N	N	N	N	N	N	N	N	N	Y
Cantara	N	N	N	N	N	N	Y	Y	Y	Y
Octavia	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Omar	N	N	N	Y	Y	Y	Y	Y	Y	N
Lufti	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Yasin	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Eisa	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Adya	Y	Y	Y	Y	Y	Y	Y	Y	Y	N

Note. Y: the student participated in the method; N: the student did not participate in the method.

Phase I participation. During Phase I, five participants (male = 3; female=2) completed the pre- and post S-STEM survey as well as open-ended questions. Due to the level of SLA of the participants, the open-ended questions had spelling and grammar issues; however, the central points for thematic analysis could be discerned and analyzed.

Phase II participation. During Phase II, the sample grew to nine participants (male = 7; female = 2). Responses to open-ended questions during this Phase increased slighting in complexity. The answers were clear and more themes emerged due to the increase in participation as well as knowledge of the English language.

Phase III participation. In Phase III, ten members of the case group (male = 7; female = 3) participated in the pre-/ post S-STEM survey. During this Phase, open-ended questions showed a variety of themes and responses were clear. From the full case study of thirteen participants, eight participated in the interviews (male =5; female = 3). During the interviews, three of the participants needed the translator to support communication. These students completed some of the interviews independently; however, peer translators assisted when communication decreased and body language assessed by me, the interviewer, showed a struggle in communication (e.g., wide eyes, eyebrows raised, shoulders raised, no talking, saying "I don't know", etc.). The peer translator repeated questions where confirmation was needed to ensure that all responses were detailed and clear.

4.3 Data Analysis

4.3.1 Quantitative analysis. Each participant was assigned a unique code, which was used to identify them across the three Phases of the study. All S-STEM pre-post survey responses were inputted into Microsoft Excel, following the numerical Likert scale responses. As a validity measure, some questions are reversed within the S-STEM survey. The numerical

values for those items are flipped. That is, 4 is entered as 2, 5 is entered as 1 and vice versa.

There was variation in the wording across certain statements to capture participants' attitude

from different angles (Figure 8).

	Strongly Disagree	Disagree	Neither Argee nor Disagree	Agree	Strongly Agree
4. I am the type of student who does well in math.	O	O	O	O	O
8. I am good at math.	O	O	O	O	O

Figure 8. Variation in wording of S-STEM statement for the mathematics construct.

The mean across participants was calculated for each statement within the scale, and then the

responses were collapsed to show a mean for each point of data collection to illustrate a single

set of means.

4.3.2. Survey scales. The statements analyzed in this thesis to explore the research

questions pertaining to attitude towards and interest in STEM subjects as well as self-efficacy in

STEM are listed below.

1. Attitude and interest in STEM subjects

Engineering & Technology

- I like to imagine creating new products;

- If I learn engineering, then I can improve things that people use every day;

- I am curious about how electronics work; and

- I would like to use creativity and innovation in my future work.

Mathematics

- Math has been my worst subject [*reversed*];

- I would consider choosing a career that uses math;

- I can handle most subjects well, but I cannot do a good job with math [*reversed*]; and

- I am sure I could do advanced work in math.

Science

- In general, I enjoy science;

- I believe science is interesting;

- I would consider a career in science;

- I can handle most subjects well, but I cannot do a good job with science [*reversed*];

- I am sure I could do advanced work in science;

- I am involved in science activities outside of school; and

- I would like to be a scientist.

2. Self-efficacy in STEM

Engineering & Technology

- I am good at building and fixing things; and,

- I believe I can be successful in a career in engineering.

Mathematics

- Math is hard for me;

- I am the type of student who does well in math;

- I can get good grades in math; and,

- I am good at math.

Science

- I am confident in my ability to do science;

- I am confident when I do science;

- I know I can do well in science; and,

- I am good at science.

21st Century Learning Skills

- I am confident I can lead others to accomplish a goal;

- I am confidence I can encourage others to do their best;

- I am confident I can help my peers; and,

- I am confident I can include others' perspectives when making decisions.

4.3.3 Qualitative analysis. Workshop observations, interviews, and open-ended questions constitute the qualitative data used in the thesis. The workshop observations underwent an analysis slightly different than the interviews and open-ended questions. However, all qualitative data was thematically analyzed to account for patterns across different participants during the study.

The workshop observations were inputted directly into Microsoft Word using the observation protocol (Appendix A) by research assistants. The data identifies and reports on recurring patterns and themes while also providing rich and detailed descriptions of the experiences (Braun & Clarke, 2006). Although the original protocol examined students, teachers and workshop facilitators, the analysis in this thesis focuses on the interactions between students and workshop facilitators. The workshops integrated ELLs with their non-ELL peers, and as a result, the observations show data from mainstream classes. The STOp workshops used a general script and, therefore, followed the same format regardless of changes in the value of facilitator, schools, and phase. Despite the integration, there is significance in concurrently comparing the observations of students to workshop facilitators as they interacted in the workshops as it demonstrates the pedagogies that support learning and those that are disengaging.

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The open-ended questions and interviews also underwent thematic analysis, which began

with inputting open-ended questions into an Excel spreadsheet. These items were colour-coded

based on recurring themes relative to the research questions. The interview questions were

inputted the same way and thematically organized using NVivo Version 11.4.0 – a software

program that is "designed to help you organize, analyze, and find insights in unstructured or

qualitative data like interviews, open-ended survey responses, articles, social media, and web

content" (QSR International, n.d.). NVivo was used to analyze the interviews in terms of word

frequencies by generating a word cloud that depicts repetitive words across participants and

illustrates those words' frequencies. Specifically, the word cloud makes the words used most

often larger than less common words. Frequency identification offers aid in developing common

themes within the case study. In addition, NVivo develops word trees, which considers typical

ways in which words were used across participants. These tools provided a context for exploring

self-efficacy in both STEM and SLA.

4.3.4 Quantified qualitative data. Both the open-ended questions and interviews were

quantified (Cohen, Manion & Morrison, 2011) through binary coding (0 = theme not present, 1 =

theme present, X = student left section blank) to explore thematic frequencies (Figure 9).

PHASE II (2014-2015)	PII Code	Colour Coding - Question 1A					Question 1A: What do you think is most exciting about [STOp] workshops
		1 = Color Present					**Clarity of Concepts/ Application of Curricular Content**
		0 = Color Not Present					**Collaboration and Teamwork**
							Inquiry Based Learning
							Positive Role Models/ Student Perceptions of Presenters
							Application of 21st Century Learning Skills
		Red	Green	Purple	Orange	Blue	
	STUDENT CODES	0	0	1	0	0	The inventions and experiments are the most exciting.
		0	1	1	1	0	We work in groups and share ideas, the [STOp] give us positive ideas about the topic we do experiments and explore new things.
		0	1	1	0	0	Team work, I like the activities.
		0	1	1	0	0	That we have to be in groups and we build objects.
		0	0	1	0	0	The most exciting part about [STOp] workshop is the building.
		1	1	0	0	0	The most exciting thing was working together the competition and a bit info on the topic.

Figure 9. A sample of quantified open-ended questions using Microsoft Excel

The themes generated were highlighted using a mix of pie charts and bar graphs to illustrate thematic change over time in the findings section.

Chapter 5: Findings and Analysis

This chapter presents the results of the study. It provides answers to the two research questions: (1) do STEM workshops, as a form of CBI, affect middle school ELLs attitudes and interests in STEM over time?; and (2) do STEM workshops affect ELLs self-efficacy, in terms of fostering both STEM and L2 identities in middle school students? The findings illuminate how STEM outreach programs support SLA and STEM concepts concurrently to cultivate a positive attitude towards and an interest in STEM subjects by grade eight. This is foundational for future STEM pathways (Cannady, Greenwald & Harris, 2014), in addition to supporting ELLs self-efficacy in STEM and their L2.

The first section of this chapter examines the impact of ELLs' long-term participation in STEM workshops. It highlights how access to opportunities that foster active STEM learning and promote learner autonomy affect ELLs' attitudes towards and interest in STEM over time. The second section presents an analysis of data based on indicators of self-efficacy and discussions around how various elements of self-efficacy in both STEM and SLA developed as a result of ELLs' participation in the workshops. The phenomenon appears in multiple data sets and analysis of repeated measures.

I organize this chapter through a division of the two research questions thematically as *Attitude and Interest in STEM* and *Self-Efficacy in STEM and SLA*. Data exploring attitudes towards and interest in STEM on which I rely in this thesis include: (a) workshop observations; (b) pre-/ post S-STEM survey; (c) open-ended questions; and (d) interviews. Two of the data collection tools unpack self-efficacy for analysis. These instruments include: (a) pre-/ post S-STEM survey; and (b) interviews. Given the nature of self-efficacy and the overlap with attitudes and interests in STEM, data emanating from the workshop observations inform perspectives

uncovered by the interviews and the S-STEM survey. By showcasing the findings in this way, the thematic overlap confirms and isolates various components of the workshop that impact ELLs' attitude, interest, and self-efficacy. Furthermore, the amalgamation of qualitative and quantitative data addresses why and how the approaches affect ELLs.

5.1 ELLs' Attitude and Interest in STEM

During data analysis of workshop observations, the S-STEM survey, open-ended questions, and interviews, several themes emerged emphasizing the pedagogies used by STOp in supporting the development of ELLs' attitudes towards and interest in STEM subjects. These topics include 21st century learning skills such as creativity, collaboration, critical thinking, and communication, as well as opportunities to "do" STEM.

5.1.1 Workshop observations. The workshop observation data identify three pedagogical approaches used by STOp (Figure 4). These are: (a) lectures; (b) demonstrations – both active and passive; and (c) hands-on activities. The following analysis situates the student responses to the pedagogical approaches used by STOp.

5.1.1.1 Workshop lecture observation synopsis. Workshop facilitators began workshops with introductory lectures that emphasized the big ideas to be explored as well as preliminary concepts. Workshop facilitators then connected the workshops to their professional background and provided students with an anticipatory sequence of events. I thematically tagged student responses to lectures based on the following themes:

- personal conversations (Flight Workshop Observations, 2014; Flight Workshop Observations, 2015; Structures and Mechanisms Form and Function Workshop Observations, 2015; Fluids Workshop Observations, 2016);

- anticipatory hypotheses between peers regarding upcoming activities (Flight Workshop Observations, 2015); and

- tactile manipulation (Flight Workshop Observations, 2014; Flight Workshop Observations, 2015; Fluids Workshop Observations, 2016).

Personal conversations were understood as behaviours recorded where students spoke among each other while the workshop facilitator lectured. This is a pedagogical approach that assumes participants listen attentively. Topics of discussion may or may not relate to STEM concepts. Student-to-student discussions were personal in nature and perhaps reflect that students were not entirely engaged in the lecture component of the workshop. During the grade seven *Structures and Mechanisms Form and Function* workshop, a group of students were observed looking away from the workshop facilitator and talking about the bulletin board (Workshop Observations, 2015). Additionally, during the grade eight *Fluids* workshop, students were observed discussing their own experiences with fluids as a STEM concept (Workshop Observations, 2016). Both of these anecdotes suggest lack of student engagement with the lecture component of the STEM workshops.

Anticipatory hypotheses between peers regarding upcoming activities recorded student discussions and level of enthusiasm as they examined the learning environment in search of manipulative and material displays, and speculated about their use in scheduled activities. Although these student observations indicated positive signs of eagerness from the participants (e.g., smiling, pointing, STEM-related discussions, etc.), it is inferred that they are listening to the workshop facilitator during the lecture. Therefore, in context of the pedagogical approach, these discussions indicate disinterest in the lecture model. During the grade six *Flight* workshop, students were observed pointing to the blow dryers affixed to their tables and predicting how

they would be used to demonstrate concepts of flight reviewed during the introductory lecture. One male student commented, "Guys! Look at this! *Points to a small airplane* I wonder what this is going to be used for? Are we going to fly it with the blow dryer?" (Workshop Observations, 2015).

Finally, students were documented manipulating personal and/or workshop items – behaviour that I label in this analysis as *tactile manipulation* – instead of paying attention to the lectures. These items were workshop materials placed in the centre of the table (Flight Workshop Observations, 2014; Flight Workshop Observations, 2015; Fluids Workshop Observations, 2016) or personal items (Flight Workshop Observations, 2015). During the *Fluids* workshop, a group of students were recorded touching and smelling the cubes made of various materials that were left on their table for an upcoming activity while the workshop facilitator discussed the formula to calculate volume (Fluids Workshop Observations, 2016).

5.1.1.2 Workshop demonstration observation synopsis. Analysis of demonstrations indicates that STOp uses two approaches. Some demonstrations were *passive* and similar to lectures in that the workshop facilitator led the instruction, while a few participants participated in an activity using manipulatives that supplemented the theories under discussion during the workshop (Flight Workshop Observations, 2015, Fluids Workshop Observations, 2016). Observations recorded for passive demonstrations paralleled similar responses as lectures (e.g., personal conversations and tactile manipulation). Additionally (likely because demonstrations occurred later in the workshop than introductory lectures), *docility* was a response to passive demonstrations in place of *anticipatory hypotheses regarding upcoming activities*. In this thesis, I define docility as body language that suggests lack of active participation and engagement; student may or may not make eye contact with the workshop facilitator, and appears lethargic.

The student may also be slouching and resting their heads in their hands. During the demonstration in the fluids workshop, a student was covering her ears as she rested her head on the palm of her hands before she proceeded to engage in personal conversations with her peer while the workshop facilitator was using three student volunteers to model pneumatic systems (Workshop Observations, 2015).

Although some of the demonstrations used a passive model, most required active participation from both the student volunteers and observing participants – especially during demonstrations that tested student creations. I have thematically tagged student responses to active demonstrations in Excel based on the following themes:

- Anticipatory hypotheses between peers regarding the outcome of design testing (Flight Workshop Observations, 2015; Structures and Mechanisms Form and Function, 2015);

- physical engagement (Flight Workshop Observations, 2014; Flight Workshop Observations, 2015; Structures and Mechanisms Form and Function Workshop Observations, 2015); and

- enthusiastic vocal responses (Structures and Mechanisms Form and Function Workshop Observations, 2015; Fluids Workshop Observations, 2016).

Throughout the active demonstrations that tested student creations, participants were observed making predictions about the success of a particular design and discussing evidence to support their predictions. During the workshop for grade seven structures and mechanisms, while testing bridges for their ability to bear weight, students consulted with one another as to whether the bridge could withstand testing. These conversations referred to engineering concepts embeded in the design to support their hypotheses, such as the use and placement of triangles (Structures and Mechanisms Form and Function Workshop Observations, 2015). One of the

discussions between two male students had them pointing to a bridge supported on one side by triangles and the other by quadrilaterals, with sides that angled inward (like a triangle). The video recording of the discussion shows the student pointing and running his finger along the top of the quadrilateral, laughing, and saying to his peer: "this one is going to go, man." This student predicted failure on one specific side of the bridge design (Structures and Mechanisms Form and Function Workshop Video Documentation, 2015) (Figure 10).
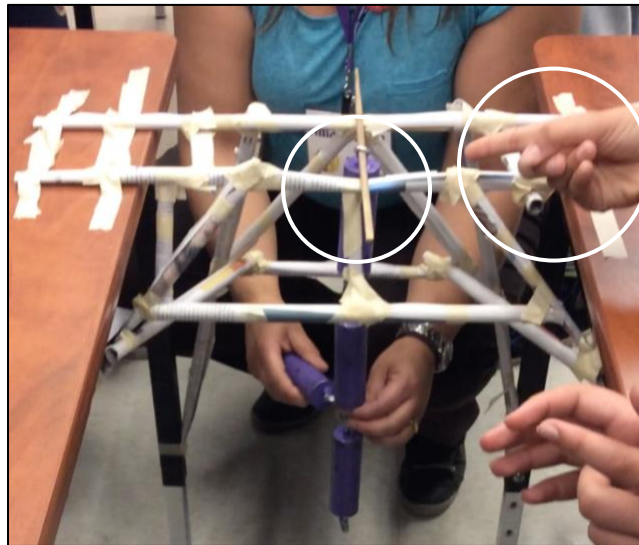

Figure 10. Sample testing comparing types of triangles.

As predicted, the side of the bridge using quadrilateral supports was the first to buckle after placing four weights on it. These hypotheses confirm an interest in the demonstration of STEM engineering concepts.

　　Physical engagement refers to student body language exhibiting active attention and kinesthetic participation during the STEM workshops. Students placed themselves in locations that ensured their involvement in the demonstration. Students smiled and sustained eye contact with the tested designs as they pointed to specific components to support their hypotheses. They

also found ways to ensure they could view and participate in active demonstrations, such as standing on tables to see over their peers (Figure 11).

Figure 11. Bridge testing demonstration from #2 "Structures and Mechanisms"

The grade six flight workshop used both passive and active demonstrations to illustrate how the elevators on a plane affect flight patterns. The workshop facilitator chose a volunteer from each table group to stand at the front of the room and gave each a paper airplane with cuts along the back of the wings which simulated the elevators. For a few minutes, the WF discussed components of a plane and pointed to her model as she discussed the properties of flight. During this time, student volunteers and observers showed signs of docility and disinterest. Students were leaning away from the presenter while supporting their head with the palm of their hand and in a slouched posture (Flight Workshop Observations, 2015) (Figure 12a). The body language of both the volunteers and the student observers changed when the student volunteers began folding the elevators and throwing their paper airplanes. Postures straightened and when throwing the airplanes at the student observers, they laughed, smiled, took note of the flight pattern and blocked their bodies from being hit by the paper airplanes (Flight Workshop Observations, 2015) (Figure 12b). The participants' body language during active and passive

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demonstrations are very different. Passive demonstrations yielded physical disengagement and body language that could be inferred as boredom, or docility (Figure 12a). In contrast, when workshop facilitators used an active demonstration model where both the student volunteers and observers could be kinesthetically attentive, students' body language showed signs of physical engagement and the response was positive (Figure 12b).

a) **Passive:** WF discussing concepts with plane prop.

b) **Interactive:** Student volunteers throwing their paper airplanes at student observers.

Figure 12. Comparison between interactive and passive demonstration

The final indicators of student engagement and interest during active demonstrations were *enthusiastic vocal responses* from participants. These responses included audible gasps, laughter, and exclamations. Vocal responses occurred either as an anticipatory response, such as a roll of newspaper beginning to buckle from the weight test but has not yet collapsed (Structures and Mechanisms Form and Function Workshop Observations, 2015), or a response to an event that occurred such as paper airplanes thrown at observers. During the paper airplane demonstration, students quickly raised their arms to protect their faces and made a loud "ah!" sound followed by laughter (Flight Workshop Observations, 2015). Additionally, during weight testing on newspaper bridges, when the bridge broke from the weight test, students let out a

synchronized "awww" sound, (Structures and Mechanisms Form and Function Workshop Observations, 2015). Given that these audible responses correlate with the phenomena being observed, they were inferred as positive and engaged responses from students.

When the emphasis was on testing and analyzing student designs, the student observations showed active engagement through body language and discussions. Students made predictions on the quality of creations and discussed why the structures and designs would be successful or not. Students were observed standing on desks, pointing and gasping loudly during active demonstrations. Alternatively, in passive demonstrations with few student volunteers highlighting concepts while the workshop facilitator lectured, signs of disengagement and boredom were common and could be discerned through body language and personal conversations among the participants.

5.1.1.3 Workshop hands-on activities observation synopsis. Students held the hands-on pedagogical model used by STOp in the highest regard. From the larger dataset, those with learning disabilities to language barriers to identified exceptional learners and everything in between, believed that they had benefitted from the experience of engaging in STEM activities as an option to learn. The following themes were identified during the analysis of workshop observations:

- active participation (Flight Workshop Observations, 2014; Flight Workshop Observations, 2015; Structures and Mechanisms Form and Function Workshop Observations, 2015; Fluids Workshop Observations, 2016);

- STEM-centered discussion (Flight Workshop Observations, 2014; Flight Workshop Observations, Flight, 2015; Structures and Mechanisms Form and Function Workshop Observations, 2015; Fluids Workshop Observations, 2016); and

- collaboration and problem-solving (Flight Workshop Observations, 2014; Flight
  Workshop Observations, 2015; Structures and Mechanisms Form and Function
  Workshop Observations, 2015; Fluids Workshop Observations, Fluids, 2016).

Active participation refers to students' execution of STOp activities in the course of applying STEM concepts and theories. STOp provided ELLs with numerous opportunities to engage with STEM. Some activities were more closed-ended. Among them were a series of pre-designed hydraulic and pneumatic systems (Fluids Workshop Observations, 2016) and specific materials used to engineer a propeller blade (Flight Workshop Observations, 2014; Flight Workshop Observations, 2015). Other activities were more open-ended. Such activities had a single understood goal, but the method of its realization was not predetermined. For example, sudents were asked to design a product reflective of the concepts related to a bridge or cantilever (Structures and Mechanisms Form and Function Workshop Observations, 2015). Students were eager to rotate through roles and exercise leadership at various levels to contribute to the group's design goals. I consider the level of students' participation in the activities to be an indicator of their interest in STEM. There were no indications in the workshop observations of disengagement or passive behaviour during hands-on learning activities.

STEM-centred discussion refers to student discussions / dialogue / conversations about STEM theories in which they engaged while applying the theories to hands-on tasks. Student conversations were centred on the STEM principles that they had learned during the workshop as well as personal knowledge and experiences. During the grade-seven workshop investigating structures and mechanisms, following an introduction to the culminating challenge of designing a bridge one student exclaimed "Yo, I did this in grade 5. We got this." He subsequently discussed the best approach to designing a bridge out of newspaper with his group (Structures

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and Mechanisms Form and Function Workshop Observations, 2015). It was also noted in the workshop observations that conversations that occurred during the hands-on activities were not limited to English and preceded problem-solving for ELLs. While designing and building their bridge, a group of male ELLs were observed communicating in Arabic. When asked about their communication in Arabic, the students explained that they had all come to Canada recently and that it was easier for them to communicate in Arabic with each other (Structures and Mechanisms Form and Function Workshop Observations, 2015). Student conversations about STEM indicate interest because they had the freedom to discuss anything during activities; however, they chose to discuss their STEM learning and approaches to problem-solving. The students were excited while thinking and communicating ways to approach the hands-on task.

Collaboration and problem-solving refers to discussions between peers followed by implemented actions to accomplish the goal of a functional product. Collaboration and problem-solving occurred either between individual group members or between different groups that were successful in accomplishing the objective(s) of the hands-on activity. Students contributed to the groups' performance through various leadership roles, which involved trying different ways in which the goal of the hands-on activity could be realized. During the grade-eight workshop that focused on fluids, a group of male students worked together as they engaged in an activity comparing the properties of pneumatic and hydraulics systems. One of the students pushed air into a syringe that lifted the dumping bed; however, the dumping bed was tilted backward. A student from another group approached and said: "You have to push it down to make it work." The student then moved the dumping bed, so that it rested on the syringe. Another member of the group responded, "Put it down", and placed the truck flat on the desk. The male student who initially took leadership manipulated the syringes for a few seconds. Then he said to the other

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group member, "Would you like a turn?" as he passed the pneumatic system to that student (Fluids Video Documentation, 2016). This vignette illustrates how activities allowed for fluid roles of leadership and provided opportunities for problem-solving and collaboration with other groups. Students were determined to work together to accomplish the goal of the activity.

The job of the workshop facilitator was to circle the room and observe, prepare for upcoming activities and demonstrations, and assist where needed. When students encountered a problem, the workshop facilitator provided guidance to stimulate student understanding before returning to their observational role. This approach gave students ownership of their learning as well as encouraged student-led creative problem-solving. For example, one student was having some difficulty making his propeller turn, so another student interjected and told him to try the successful propeller her group had created. Through exploration and workshop participation, students developed peer learning networks (PLNs) that supported their STEM interests. In the scenario outlined above, the student compared her propeller model to the successful design created by her peer. This student made changes to her design based on her model and, thus, successfully built a working propeller. Between opportunities for collaborative problem-solving and the scaffolding role of the workshop facilitator, the workshops provided ELLs with a buffer that motivated the participants to persevere through challenges and take ownership in both their academic and linguistic education.

The hands-on activities gave ELLs autonomy over how they navigated their language learning. ELLs established support networks within their classes to assist when they encountered a challenge caused by a linguistic barrier. They often chose to approach their peers, rather than adults, to ask for help. ELLs could articulate and formulate their ideas without reliance on their L2 while learning STEM. The combination of hands-on learning and collaboration, when ELLs

are given autonomy to form their PLNs for exploration is integral for nurturing interest in STEM. Without these opportunities, students miss out on exploring these interests in exchange for acquiring their L2. Table 5 provides a summary of findings related to workshop observations.

Table 5

Summary of Student Responses towards STOp Pedagogies.

| Pedagogy	Themes	Notes
Lectures	*Personal conversations; anticipatory hypotheses between peers regarding upcoming activities; and, tactile manipulation.*	**Students *were not* receptive to lectures.** Students enthusiastically anticipate the opportunities they recieved to explore and engage in hands-on learning. Although this model is teacher-led, students would disengage and partake in their student-led responses (e.g., hypotheses around activities, inferencing and applying previous knowledge to STEM topic, etc.)
Passive Demonstrations	*Personal conversations; docility; and, tactile manipulation.*	**Students *were not* receptive to passive demonstrations.** Observations included signs of docility and boredom lacking active participation and engagement.
Active Demonstrations	*Anticipatory hypotheses between peers regarding the outcome of design testing; physical engagement; and, enthusiastic vocal responses.*	**Students *were* receptive to active demonstrations.** An effort was autonomously made by students to physically interact with the demonstrations. Participation varied depending on whether students were chosen by the WF to be a volunteer or if they were the observer. Student observers would discuss and engage with their peers during active demonstrations.
Hands-on Activities	*Active participation; STEM communication; and, collaboration and problem-solving.*	**Students *were* receptive to hands-on activities.** Observations showed high levels of engagement and participation in activities. Hands-on activities were described as a positive learning experience by and for the students.

5.1.2 The S-STEM survey: quantitative comparison of STEM subject Interest. This analysis focuses on ELLs' perceptions of STEM through the scales that address attitudes towards and interest in specific STEM subjects (see section 4.3.2.). The mean was calculated across the participants for each pre- and post- S-STEM survey distributed during the three Phases. The averages of each question were then collapsed to display a single score of interest before and after each workshop across the three Phases. Overall, survey data reveal significant increases in attitude towards and interest in engineering and technology (Figure 13a) and mathematics (Figure 13b) over time. Additionally, insignificant decreases in attitude towards and interest in science (Figure 13c) were revealed over time.
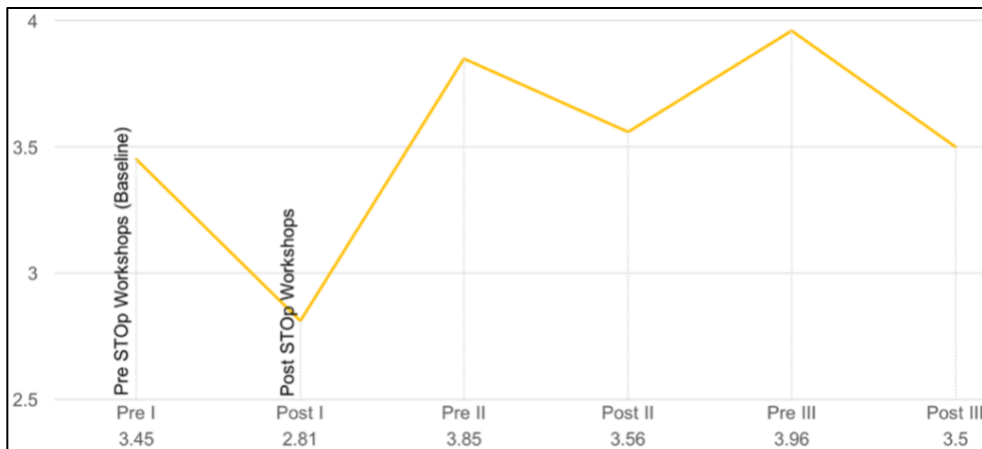
a) Attitude and interest in engineering and technology over time
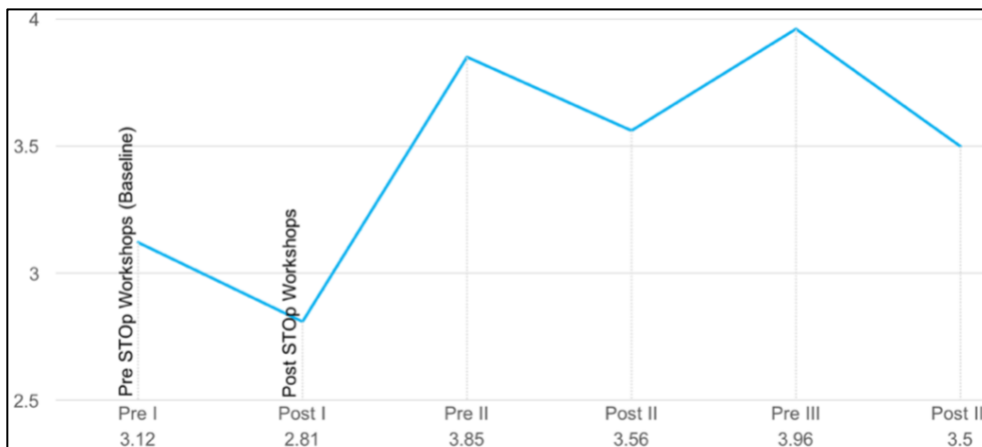
b) Attitude and interest in mathematics over time

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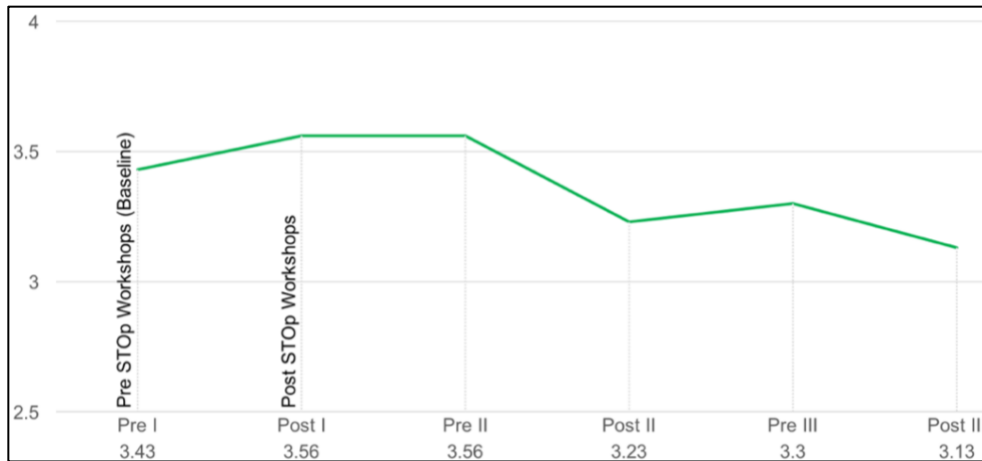
c) Attitude and interest in science over time

Figure 13. Pre-/ post-S-STEM mean averages depicting attitudes towards and interest in individual STEM subjects.

During Phase I, interest in *engineering and technology* decreased (Figure 13a). Although the workshops use a STEM interdisciplinary model, specific STEM subjects are more prominent in some workshops. The workshops provided for the grade six students during Phase I were aligned with the following Ontario Science and Technology strands: (a) understanding matter and energy – electricity and electrical devices; and (b) understanding earth and space systems – space. Both are science-forward with embedded technology, engineering, and mathematics content. As a result, interest in science increased between pre- and post Phase I (Figure 13c) while interest in engineering, technology and mathematics decreased by post- Phase I.

During Phase II, grade seven students from the ELL case study sample participated in workshops that investigated the following Ontario Science and Technology strands: (a) understanding structures and mechanisms – form and function; and (b) understanding matter and energy – pure substances and mixtures. The structures and mechanisms workshop defined engineering during the introductory lecture as well as acquainted students with various types of

engineering occupations. As a result, interest in *engineering and technology* increased substantially and remained steady until the students graduated from middle school.

During Phase III of the study, ELL students participated in workshops exploring the following Ontario Science and Technology strands: (a) understanding matter and energy – fluids; and (b) understanding structures and mechanisms – systems in action. Both workshops explored engineering concepts explicitly. Although the fluids workshop represented science equally, it emphasized the application of hydraulic and pneumatic systems with explicit reference to hydraulic engineering – a subsection of civil engineering. As a result, interest in *science* declined insignificantly by post- Phase III while *interest in engineering and technology* was sustained after the significant increase during Phase II.

Interest in *mathematics* (Figure 13b) followed a pattern similar to interest in *engineering and technology* (Figure 13a). During Phase I, interest in mathematics was low and declined slightly until post Phase III. This pattern can be attributed to a similar experience with the workshops that supported interest in *engineering and technology* as engineering is a practical application of science and mathematics. Furthermore, the K-8 level focuses on foundational mathematics which is simpler to interpret between languages.

Interest in *science* (Figure 13c) started out high and was sustained with an insignificant gradual increase by post-Phase I and pre-Phase II. After exposure to the engineering-forward STEM workshops, there was an insignificant decline in interest in *science* by grade eight. To isolate the effect of hands-on learning on attitudes towards and interest in science, students were asked in the S-STEM survey how much they agree with the following statement: "Hands-on activities in my science class increase my interest in science." ELLs interest in science increased when they engaged in hands-on activities (Figure 14). It is important to note that pre-Phase I

scores serve as baseline data wherein the ELL participants had no previous experiences with STOp.
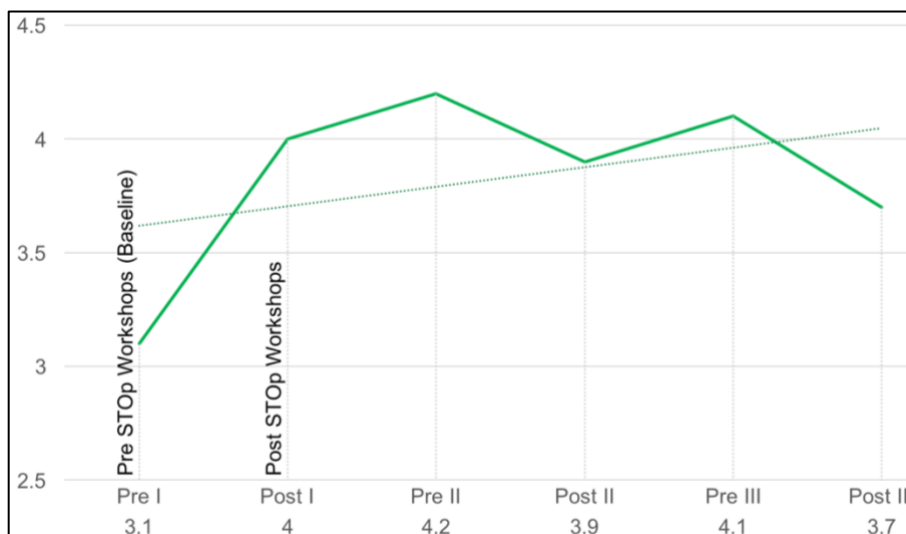

Figure 14. Pre-/ post S-STEM survey mean averages depicting the impact of STOp hands-on activities on ELL's interest in science.

A comparison of Figure 13c and Figure 14 shows interest in science moving in two separate directions. In Figure 13c, the data shows an insignificant decline in interest in science for ELLs, however, when interest in science was analyzed separately with hands-on activities as a dependent variable, interest increased significantly over time. Figure 14 also depicts a significant increase in interest between pre-Phase I and post- Phase I. This data illustrates that opportunities for hands-on learning provided by STOp are paramount in supporting interest in science for ELL students.

When ELL students have reduced barriers in their ability to learn, they tend to develop an interest in the topic. When ELL students struggle to comprehend academic concepts while concurrently acquiring an additional language, capacity to understand becomes twofold. Students need to decode the expressed information and figure out what it means for acquiring the content knowledge. This process is laborious in comparison to their English-speaking peers – who are

also not keen on the teacher-led lecture model that I have outlined in the workshop observations. To pinpoint where the disinterest in science develops, the pre-S-STEM survey asked students to respond to the following two prompts: (a) "The science we do in class makes me interested in science"; and (b) "The science we do in class helps me develop a more positive attitude towards science." The post-S-STEM survey asked students to respond to the following three prompts: (a) "I enjoy learning science, technology, engineering and/or math with [STOp]"; (b) "[STOp] workshops have made me more interested in science, technology, engineering, and/or math"; and, (c) "[STOp] workshops helped me develop a more positive attitude towards science, technology, engineering and/or math." The means from the post S-STEM surveys provide a comparison between classroom science and the STEM workshops (Figure 15). Dividing these variables for comparison uncovers which approach to STEM education adequately supports ELLs in developing a positive attitude towards and an interest in the subjects. Furthermore, this data supports the argument for considering ways that schools and outreach programs can collaborate.
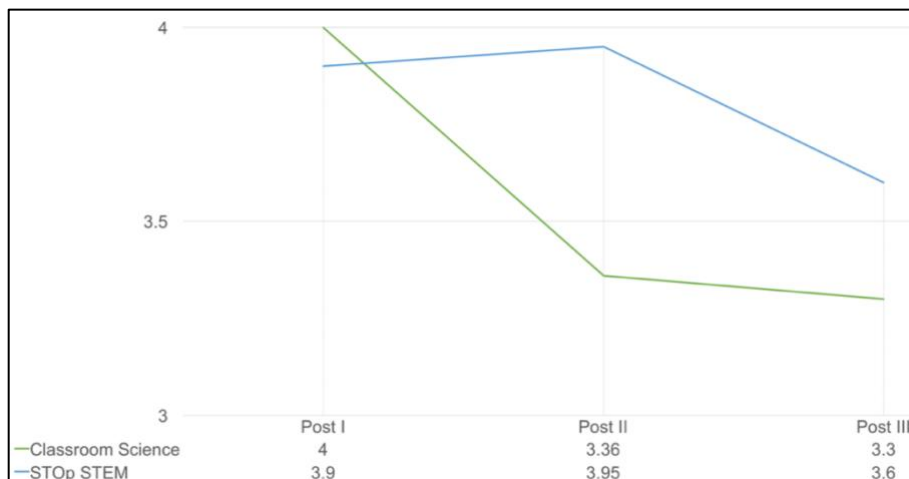

	Post I	Post II	Post III
—Classroom Science	4	3.36	3.3
—STOp STEM	3.9	3.95	3.6

Figure 15. STEM attitude and interest fostered in classroom vs. STOp workshops.

During Phase I, classroom science education supports interest slightly more than the STOp workshops; however, this comparison is insignificant – both results begin around the same point. By Phase II, the grade-seven ELLs' responses show an increase in interest in science with STOp in comparison to classroom science instruction, which decreases significantly. By Phase III, interest in the STOp workshop's approach to science instruction declined insignificantly while classroom science instruction sustained between Phase II and Phase III. Although both variables see a decrease in interest by grade eight, there is a distinct difference in the rate of decrease. By working with outreach programs, students can maintain a higher level of interest in STEM subjects by the end of grade eight. Below is a list of key findings from the S-STEM survey.

Summary of attitude and interest key findings from S-STEM survey

- Interest in engineering, technology, and mathematics increases over time;

- interest in science decreases over time;

- interest in STEM subjects aligns with the type of workshops chosen for the students to participate in;

- opportunities for hands-on learning in science increases the ELLs' interest in the subject; and

- partnering with STEM outreach programs supports interest in science for ELLs during the academic transition towards abstract science curricular concepts.

5.1.3 Open-ended questions: a thematic analysis of ELL interest in STEM. Students were asked a variety of open-ended questions with a goal of expanding on their responses to various statements from the S-STEM survey. Because the open-ended questions require written communication skills and the cohort was in the process of acquiring the English language, the

thematic responses complemented their process of SLA. This section presents the qualitative and quantitative thematic analysis of the open-ended questions.

5.1.3.1 #1A What do you think is the most exciting about [STOp] workshops? I have divided participants' responses to this question into multiple themes; some responses were consistent across the three phases, while others appeared or were collapsed or nested to form a different theme. Hands-on learning was consistently identified as the most exciting element of the STOp workshops across all three Phases (Figure 16 a,b,c). Bearing in mind the ELLs progression in the process of acquiring English, the themes that emerge transition from *navigating STEM as an ELL* in Phase I (Figure16a) to *establishing their ideas, autonomy, and identities within STEM* by Phase III (Figure 16c).
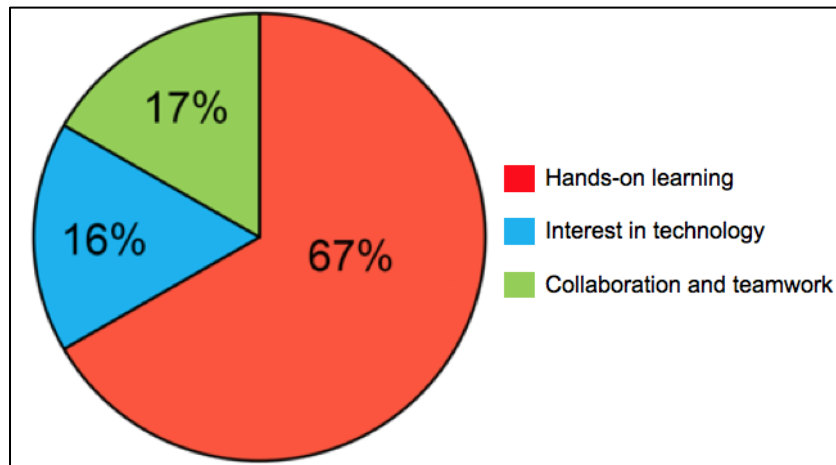
a) Phase I (2013 – 2014)
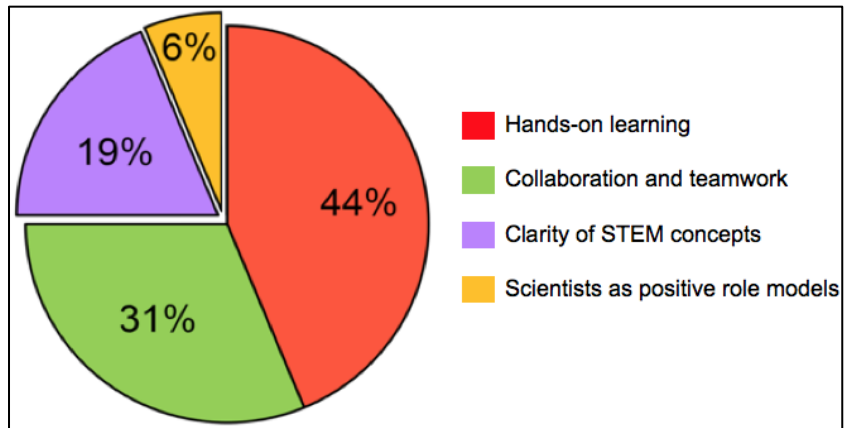
b) Phase II (2014 – 2015)
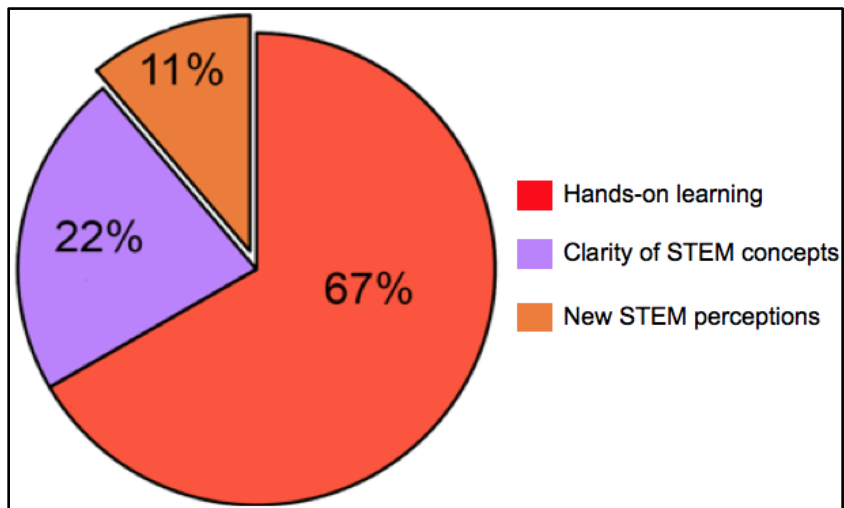
c) Phase III (2015 – 2016)

*Figure 16.* Workshop components ELLs found to be exciting.

During Phase I of the study, the ELL case study sample reported that they were excited about three specific themes: (a) hands-on learning; (b) interest in technology; and (c) collaboration and teamwork. The association between hands-on learning and interest is evident in the following responses: "The most exciting part in [STOp] workshops are the experiences we

get to do. The experiences help me understand why something happens" (Octavia, Open-Ended Questions, 2014), and "I think that when we do those new experiments which are really fun…" (Adya, Open-Ended Questions, 2014). There is significance in the student reflection expressing how the activities helped her understand why something happens. Given that the case study participants were at their lowest level of English acquisition during Phase I, the hands-on activities served as a kinesthetic language that supported their learning and bypassed the language barrier. Additionally, ELLs discussed collaboration and teamwork within their PLNs as an exciting part of the workshop experience. One student noted: "I think the most exciting thing is when in a group, we do experiments" (Lufti, Open-Ended Questions, 2014). Finally, there was an interest in one of the four STEM disciplines – technology. During Phase I, students participated in the electricity workshop that incorporated a collection of hands-on activities exploring circuits and a project in which the students created a battery. One student reflected: "I think that when we do those new experiments which are really fun because first of all we had to learn new things and we even get to know more about technology" (Adya, Open-Ended Questions, 2014).

During Phase II of the study, two new themes emerged. Not only had the participants been navigating the English language for at least a year, but grade-seven introduces engineering as a concept to the students. Two of the three themes from Phase I carried over into Phase II: (a) hands-on learning; and (b) collaboration and teamwork. Again, hands-on learning is the fundamental pedagogy used to sustain an interest in STEM subjects for ELLs. During Phase II, students reflected: "The most exciting part about [the STOp] workshop is the building" (Octavia, Open-Ended Questions, 2015), and "The inventions and experiments are the most exciting" (Cantara, Open-Ended Questions, 2015). Additionally, teamwork and collaboration was further

developed by students during the workshops. In the open-ended questions, students noted: "We work in groups and share ideas…" (Ibrahim, Open-Ended Questions, 2015), and "The most exciting thing was working together in the competition" (Salim, Open-Ended Questions, 2015). At this level, students indicated that they were excited that the workshops gave them the opportunity to work with their peers. During Phase II, two new themes emerged: (a) clarity of STEM concepts; and (b) scientists as positive role models. The emergence of clarity of STEM concepts is indicative of a positive attitude towards and an interest in STEM because students were not only able to explore STEM, but they adopted additional applied STEM learning. One student said that "The most exciting thing was …[getting] a bit info on the topic" (Salim, Open-Ended Questions, 2015), while another stated: "[The workshops] helps us know new information that we never heard of before" (Eisa, Open-Ended Questions, 2015).

At the end of Phase III, all students were considering a career in STEM (Yes n=3; Maybe n= 6; Incomplete n=1). Students were asked to select, based on a multiple-choice list, who influenced their decision to consider a STEM career during each phase of the study (Figure 17a, b, c). By Phase III, teachers, parents/ family, and the Internet were ranked as the primary influencers for 60 percent (n=6) of the participants. STOp followed as an influencer for 50 percent (n=5) of ELLs (Figure 17c). During Phase II, STOp tied with parents and family members as the primary influencer of ELLs' STEM career aspirations, accounting for 44 percent (n=4) of the total respondents (Figure 17b). STEM career aspirations are linked to interest in STEM. This is because, if students had not been interested in STEM, they would not have wanted to continue on STEM educational pathways if given an opportunity to make a different choice.
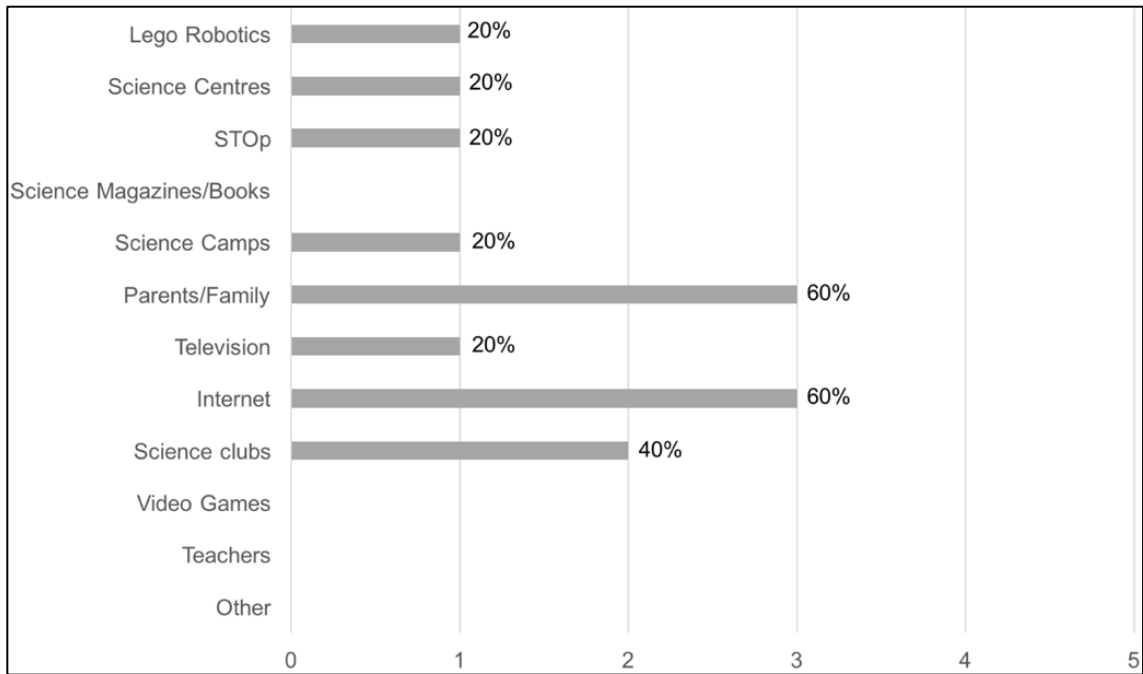
a) Phase I (2013 – 2014)
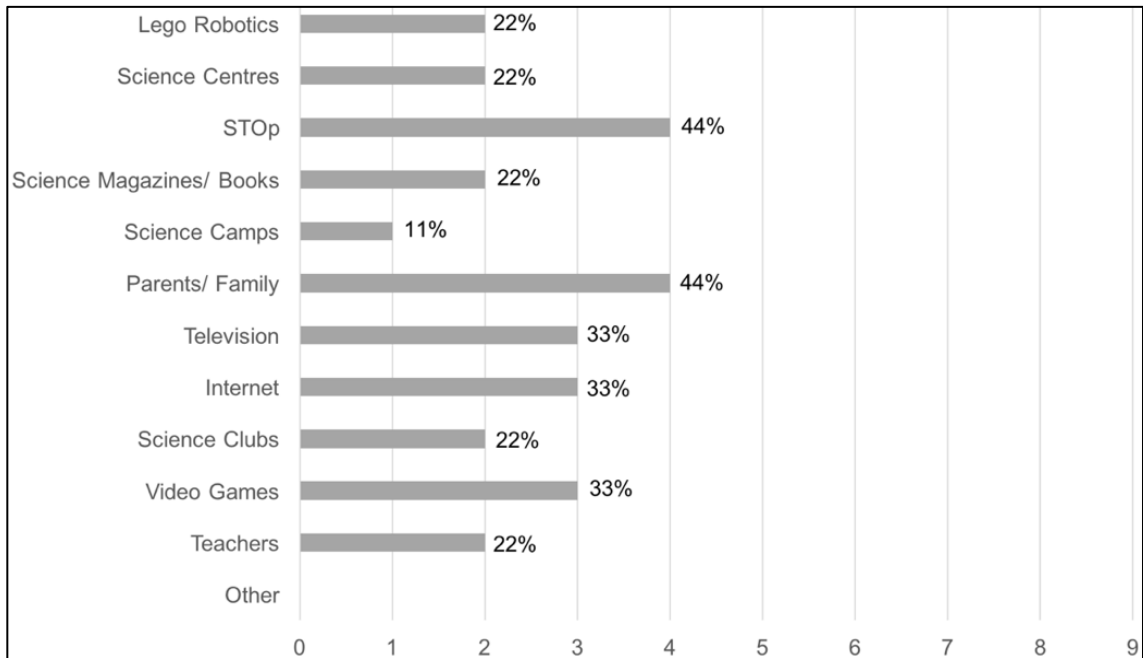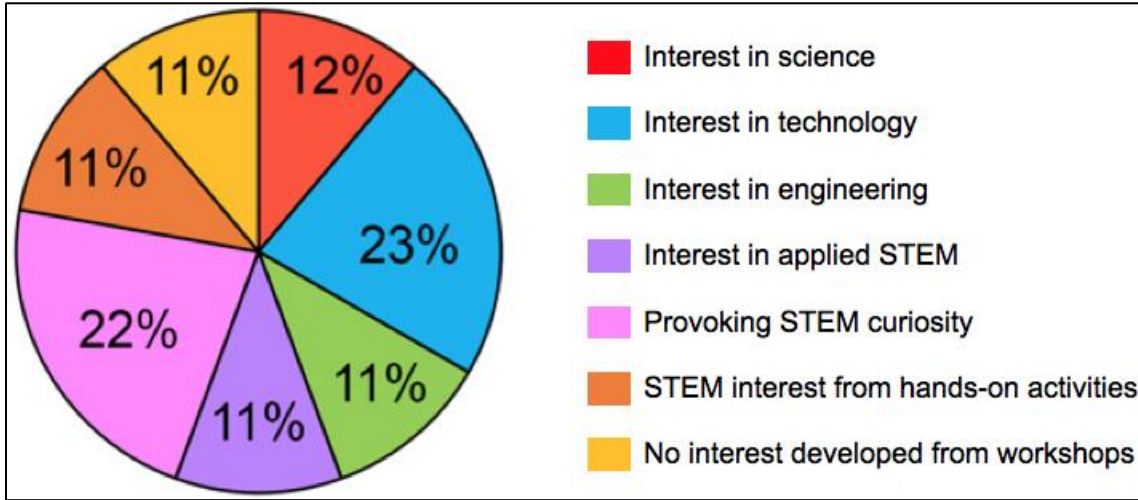

b) Phase II (2014 – 2015)
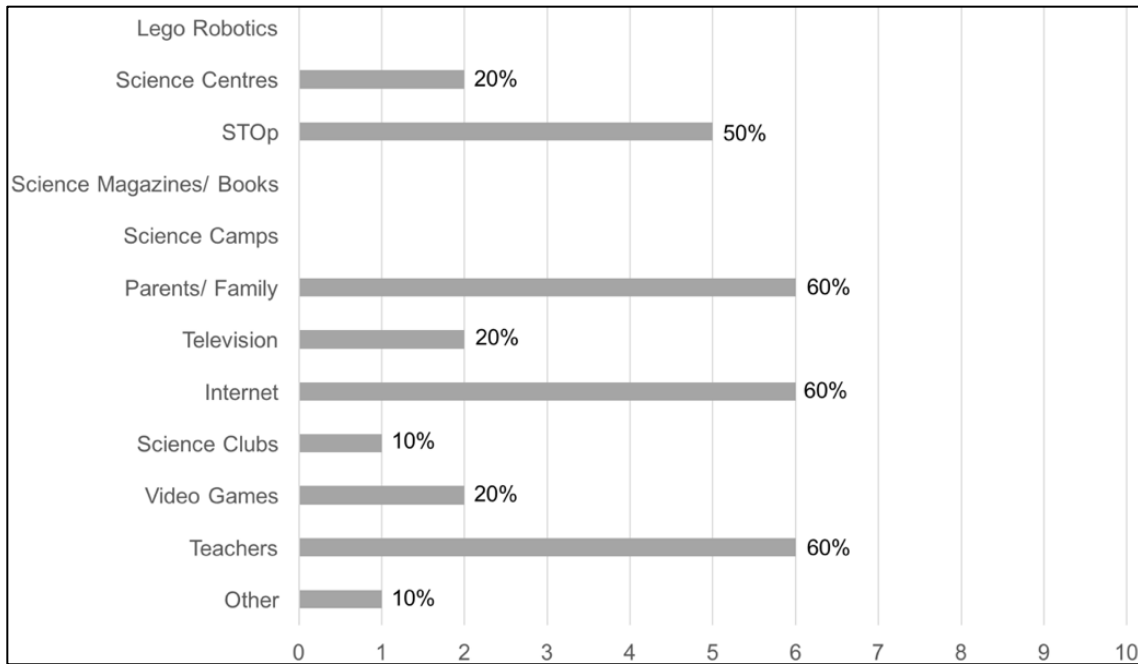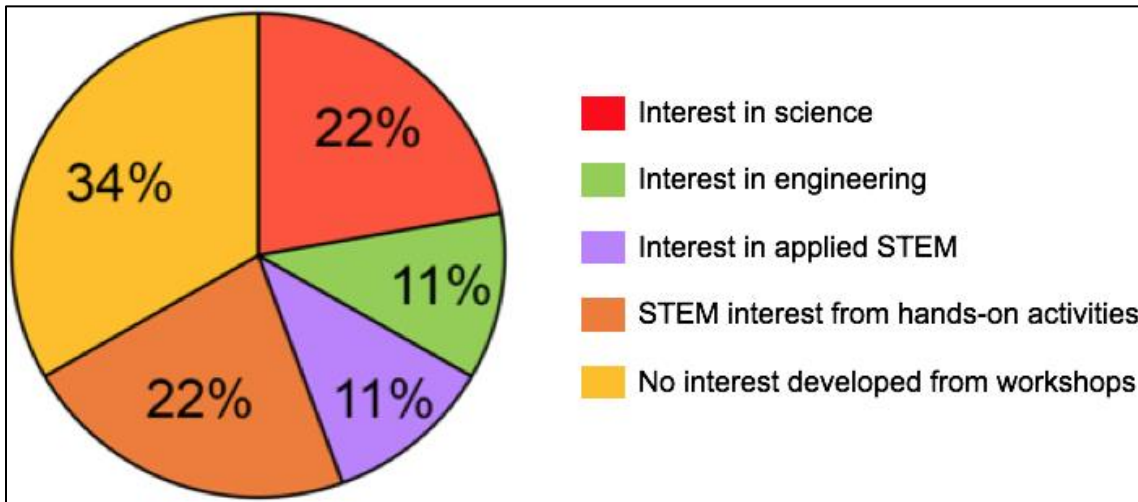
c) Phase III (2015 – 2016)

Figure 17. STEM career aspiration influencers amongst ELLs

During Phase III, *hands-on activities* were the primary support provoking a positive

attitude towards and an interest in STEM. As the ELL students developed their language ability

over the three years, a new theme emerged. Students saw a *change in their perceptions of STEM*

by Phase III. This theme connects to the hands-on activities because participants realized that

STEM does not need to be "dull". One student noted that "the most exciting thing in workshops

is their experiments. [STEM] becomes more interesting" (Adya, Open-Ended Question, 2016).

Over time, ELLs found a balance between understanding STEM and developing their interest in

STEM subjects: "I get to do activities and I get more understanding" (Salmin, Open-Ended

Question, 2016). The connection between access to extensive hands-on learning makes the

process of acquiring STEM content knowledge exciting and this, in turn, supports ELLs positive

attitudes towards and interest in STEM.

5.1.3.2 #3: Have the [STOp] workshops encouraged you to be interested in science, technology, engineering and/ or math either in school or outside of school? If so, how? This question was modified in Phase III of the post S-STEM survey to explore students' interest in specific STEM disciplines – science, technology, engineering and mathematics. The findings related to these questions are illustrated in Figure 18a, b, c.

a) Phase I (2013 – 2014)

b) Phase II (2014 – 2015)
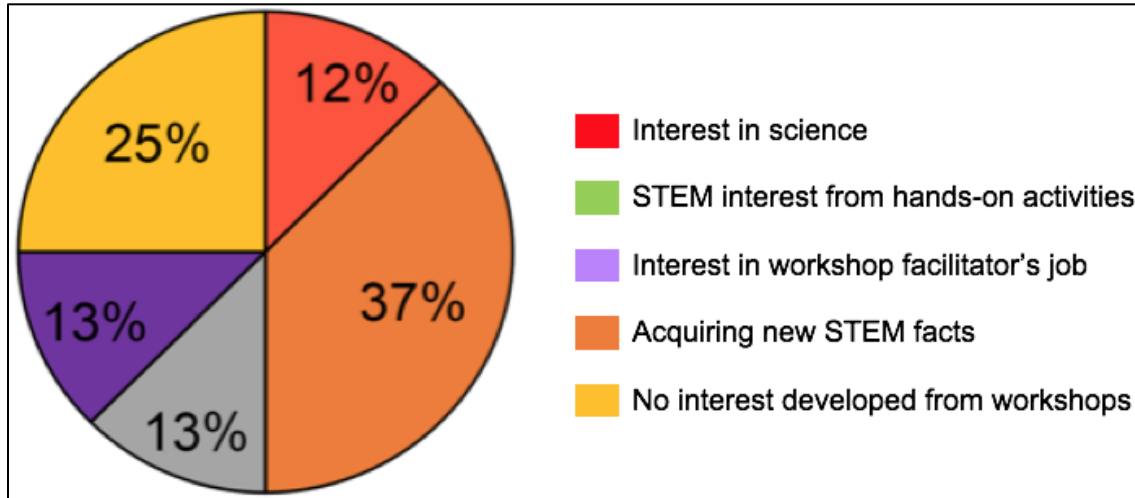
c) Phase III (2015 – 2016) (modified)

Figure 18. Students' interest in science, technology, engineering and mathematics over three phrases

During Phase I (Figure 18a), content interest was primarily in *technology* followed by *science* and *engineering*. One student noted: "[the STOp workshop] made me interested in technology because they do new experiments which makes me interested in technology" (Adya, Open-Ended Questions, 2014). As I have explained earlier, students participated in the grade six workshop that explored electricity. The theme *interest in applied STEM* and, specifically, in technology, was a component of the STOp workshop which stood out to ELL students. It accounted for 11 percent of the responses. One student explained: "Workshops have encouraged me to be interested in technology and engineering. Recently I have been wondering how phones and laptops work. I also dream about making things using electricity to help people" (Octavia, Open-Ended Question, 2014). This ELL student reflected on the application of technology and electricity in a real-world context. When students can relate their STEM learning to real-life, they make the connection between what they are learning and how it affects their lives. This realization provokes interest in STEM subjects. Octavia's response overlaps with another theme

that emerged outside the primary four STEM disciplines: *provoking STEM curiosity.* Findings reveal an association between students' curiosity in STEM and their interest in STEM subjects. Another student explained: "[STOp] show us new things which really makes me to learn more about technology" (Adya, Open-Ended Question, 2014). Adya's expression of her curiosity to find out more about technology can be attributed to the workshops. Since the case study participants' level of English fluency was lower during Phase I, she did not provide much detail, however, as the study progressed, Adya and other participants reflect deeper on the impact of hands-on learning in supporting interest in STEM.

No new themes emerged in Phase II (Figure 18b); however, some disappeared from the thematic analysis. First, interest in *technology* dissipated. In contrast, from the core STEM disciplines, interest in *science* increased from 12 to 22 percent. Students confirmed that STOp workshops enhanced their interest in *science*. One student explained: "They give me lots of positive and exciting ideas about science they also make fun contests that provide us with information and to let you have fun" (Ibrahim, Open-Ended Questions, 2015). Another said: "Yes, [STOp] made me interested in science…" (Eisa, Open-Ended Questions, 2015). During Phase II, the students had one workshop that was engineering-forward and another that was science-forward – which is likely why the interest in science and engineering sustained for this Phase. Reflecting on their interest in *engineering*, one student discussed how "[The STOp] made me interested in engineering because engineering allows you to design a structure" (Salim, Open-Ended Questions, 2015). Here, the student is interested in the practical use or application of engineering knowledge. In Phase II, the ELL cohort continued to praise the applied approach towards the STEM subjects. Their perceptions towards STEM changed during Phase II, and they could see how to use this knowledge in a real-life context. As a result, the theme *interest in*

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applied STEM remained consistent between the two Phases. One student related how STOp supported their interest in science by exploring how STEM interacted with the environment. She stated: "[The STOp supports my interest in science] …because they talk a lot about science and how it interacts with our environment" (Eisa, Open-Ended Question, 2015). Through the workshops, students made sense of how STEM affects their lives, which increased their interest in STEM. Finally, the hands-on activities provided by STOp continued to support ELL interest in STEM in Phase II. Adya explained: "[STOp] have made me more interested because they have done experiments, and those experiments have made me really interested in workshops" (Open-Ended Question, 2015). Cantara remarked: "Yes, [the STOp has supported my interest in STEM] by learning how things work … experimenting and explaining things that are new" (Open-Ended Questions, 2015).

During Phase III of the study, the question about interest in STEM subjects was modified to explore students' interest in STEM further. Interest in STEM was categorized based on the frequency of each subject and included students who did not choose a subject interest (Figure 19).
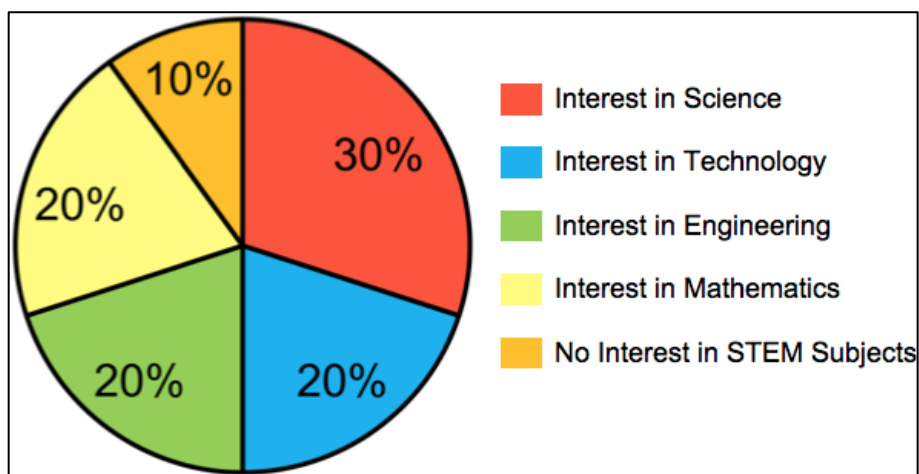

Figure 19. Open-ended thematic analysis of interest in STEM resulting from STOp workshops in Phase III

In Phase III, ELL interest in *science* was the highest and accounted for 30 percent of the responses (n=6). The additional subjects, *technology, engineering, and mathematics* each had the same frequency of interest at 20 percent (n=4) of the participants from the ELL case study. Additionally, 10 percent of (n=2) students did not feel that STOp supported their interest in STEM subjects. One student had a difficult time understanding the workshops and stated: "[The STOp did not support my interest in STEM] because every time I have [STOp], they confuse me" (Omar, Open-Ended Question, 2016). Additionally, when asked, *"What do you think is most exciting about [the STOp] workshops?"*, Omar said, "The experiments that we work on is the only reason I like it sometimes" (Open-Ended Questions, 2016). When asked *"What could [the STOp] do to improve their workshops?"*, Omar said: "Try to talk less and not be so boring" (Open-Ended Questions, 2016). Therefore, Omar's response might have been a result of his exposure to the lecturing pedagogy. That is, lecturing likely got in the way of him developing an interest in STEM subjects. As discussed earlier, when students struggle with the language, relying on a lecture approach to teach STEM creates additional challenges for students. The second student who did not think that STOp supported their interest in STEM stated: "They are not so interesting" (Cantara, Open-Ended Question, 2016). When asked *"What could [the STOp] do to improve their workshops?"*. Cantara suggested: "They could show us more about physics, for example, converting energy ex: mechanical energy to electrical energy" (Open-Ended Questions, 2016). In previous Phases, Cantara was an advocate for hands-on learning; thus, the response indicates that the Phase III workshops did not address her interest in such learning. Among the students who developed an interest in STEM because of the workshops, hands-on learning was the primary reason. Students associated fun with learning STEM when they had participated in hands-on activities. One student said that "It's fun because we make stuff" (Eisa,

Open-Ended Questions, 2016), and another stated: "The activities are fun but while doing I also get understanding" (Salim, Open-Ended Questions, 2016). *Gaining an understanding* is an example of a theme that emerged in Phase III: *acquiring new STEM facts.* By Phase III, students enjoyed the process of learning with STOp and associated the acquisition of STEM content knowledge with developing greater interest in STEM. One more theme emerged in Phase III of the study: *interest in workshop facilitators' jobs.* Here, students see STEM professionals as "fun", which is critical in supporting STEM pathways and interest in STEM subjects. One student noted that "The scientists made science really fun" (Octavia, Open-Ended Questions, 2016). By moving away from the traditional perception of scientists, participants began to bridge their interest into developing their self-efficacy and identity in STEM as ELLs. Below is a list of key findings from the S-STEM open-ended questions.

Summary of attitude and interest key findings from S-STEM open ended questions

- Hands-on learning was the most consistent and well-received component of the STOp workshops in supporting an interest in STEM over time;

- opportunities to collaborate within peer learning networks (PLNs) were an additional element that students indicated as supporting their interest in STEM;

- over time, the workshops clarified STEM content from science class for ELLs, and eventually, students began reconceptualizing their perceptions of STEM;

- the STOp supports ELL students' interest in pursuing a STEM career; and

- by Phase III, 90 percent of students from the case study had an interest in a STEM subject.

5.1.4 Interviews: ELL student voices on interest in STEM. Interviews were conducted at the end of Phase III and explored in depth themes that emerged from the other data sets. This

section probes ELLs' attitudes towards and interest in STEM through the analysis of the questions: *#4 What do you think was most exciting about [the STOp] workshops?; #5 Were the STEM activities in the workshop enjoyable? Why or Why didn't you find them enjoyable?; and #8 Have [the STOp] encouraged you to be interested in science, technology, engineering and/ or math (STEM) either in school or outside of school? If so, how?* These questions were selected for analysis as they investigate students' interests in STEM and unpack the affective dimension related to acquiring an interest in STEM subjects.

5.1.4.1 #4 What do you think was the most exciting about [the STOp] workshops?

Four themes emerged in the analysis: *(a) learn new things; (b) collaboration and teamwork; and (c) hands-on activities* (Figure 20).
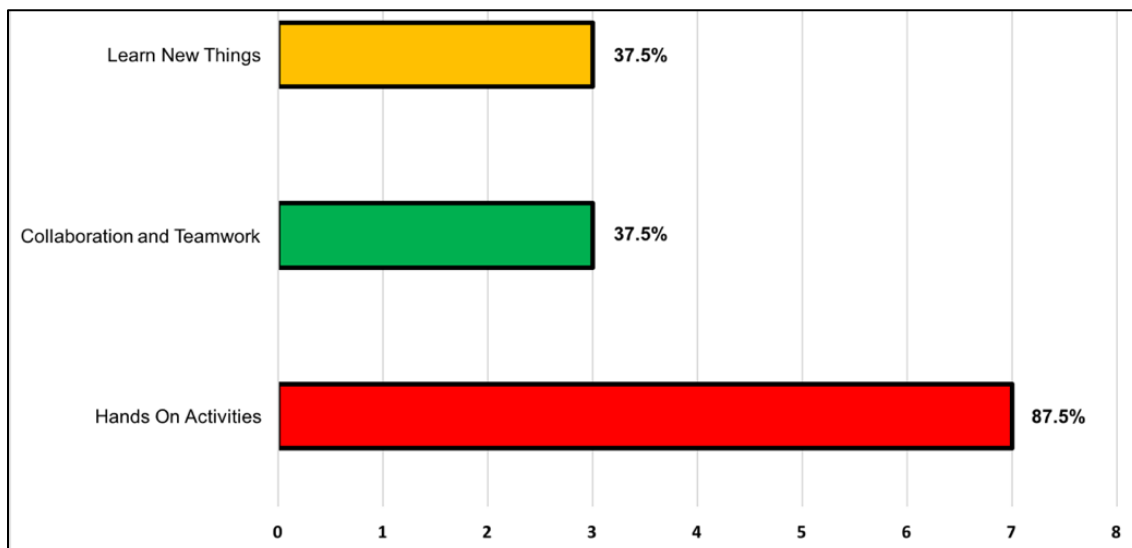
Figure 20. Themes highlighting ELLs' excitement with STOp workshops

Hands-on activities sustained as the most exciting part of STOp workshops accounting for 87.5 percent (n=7) of the participants' response from the ELL case study. During interviews, most students discussed what they did in the workshops. Responses include: "That the thing we do it's like we take a paper, we write, we do stuff like the liquid how it's a gas, yeah" (Cantara,

personal communication, 2016), and "It was fun when we made the airplane, and then we tried it out" (Octavia, personal communication, 2016). Other students reflected more generally about the positive experience of participating in hands-on activities. One student noted: "We don't just sit and write things. We do things like we build things" (Tarik, personal communication, 2016). Additionally, 37.5 percent (n=3) of the participants stated that opportunities for *collaboration and teamwork* were an exciting component of STOp workshops. When students could work together in a hands-on manner to solve problems, it cultivated their overall interest in STEM. Students reflected that "We worked together, and we helped each other to build it, and it was good, yeah" (Ibrahim, personal communication, 2016), and "I liked how you work with your friends, how you helped your friends" (Sabir, personal communication, 2016). The last theme, *learn new things* accounted for 37.5 percent of the responses (n=3). Students enjoyed when they learned something new in a manner that was different from their classroom experience with traditional science instruction. What was particularly interesting was that one student compared their experience in learning new things through a hands-on method with STOp to their science education "back home" in India. This student explained their experience in the following manner:

> There's, like, activity, but then it's also fun to do. Like, before when I was in my home
> country. They didn't show us. We just write out a question and answer it, and that's it.
> But over here, we can see ... how they do it over here, it makes me understand much
> more, and it's easier for me to understand. Like we're doing an activity which is fun,
> which is based on studying. We can study too. (Salim, personal communication, 2016)

In this discussion, Salim saw the workshops as a constructive learning experience despite his language barrier. Other students' accounts were broader about their experience with learning new things and how it was an exciting component of STOp workshops. Typically, these responses were multi-thematic and addressed the fact that learning new things through the hands-on activities was exciting. One student stated: "When we work in groups, and we work together, and we don't just sit and write things. We do things like we build things. And we learn new things" (Tarik, personal communication, 2016).

5.1.3.2 #5 Were the STEM activities in the workshop enjoyable? Why did or why did you not find them enjoyable? Four themes emerged related to hands-on learning. Participants reported that hands-on learning was enjoyable because: *(a) easier to understand; (b) learn new things; (c) collaboration and teamwork; and (d) fun* (Figure 21).
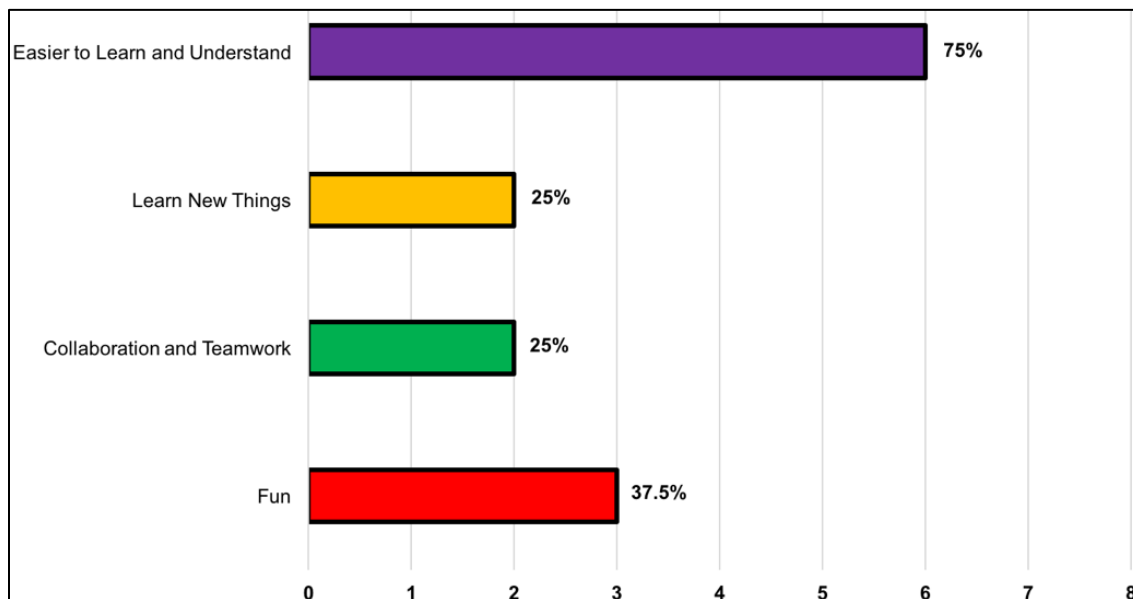

Figure 21. Themes highlighting ELLs' excitement with STEM activities

Seventy-five percent (n=6) of the participants indicated that the most enjoyable part of participating in the activities was the ease of learning and understanding STEM content. Students

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stated: "Yeah. It was fun and helpful. [*Q: What was helpful about them? Are you telling me it was fun to learn?*] Yeah" (Eesha, personal communication, 2016), and "[STEM] was like hard and easy … It was things that we didn't do it before. I only studied grade 1, 2, 3, 4. I didn't study grade 5 and 6, and so we didn't learn that science" (Ibrahim, personal communication, 2016). Given the language barrier, participation in hands-on activities made access to STEM learning easier. When students could access their understanding of STEM content, they cultivated an interest in the STEM disciplines.

Along with being able to understand, 37.5 percent (n=3) of participants found that the activities were a fun way to learn. The combination of ease of understanding and comprehension, as well as being "fun" is essential for ELL students. It is easy to disengage from content learning when one is focused on navigating the language. During the interview, one student very succinctly responded to a question about the reasons why they found the activities enjoyable by saying: "Yes. It's fun. I don't know how to explain it. For each activity, before doing, they gave instructions what to do and what to do next" (Salim, personal communication, 2016). Salim asserted that activities are an easy and fun way to learn. It is not that the STEM content itself is easy – it aligns directly with curricular expectations. Rather, it is the traditional science pedagogies being used to teach the curriculum that make it difficult to acquire content while also learning the language of instruction. The combination of *easy access* and *fun* supports interest in STEM.

Twenty-five percent (n=2) of students also indicated that they liked how the activities helped them *learn new things* as well as provided opportunities to *collaborate* and work together. The theme *learning new things* is important because it removes hands-on activities from being considered "edutainment". One student reflected that:

For me, before I came here to Canada, I didn't study grade 5 or grade 6 because I was in Syria and there was a war. So I didn't get all of that work, and so when I came here, I learned words that I don't know before, or ...I came from Syria. Then I went to Lebanon. I studied grade 7. Then I came here, and I studied grade 7 again. I studied grade 7 twice. When I lived in Lebanon, I studied for French and English … When I came here… We studied all fluid, so I didn't know that, what fluids were. (Ibrahim, personal communication, 2016)

Ibrahim missed much learning while his family was in the process of seeking refuge in Canada from Syria. Additionally, international curricular standards in Canada and other countries differ. When he came to Canada, the content and approach to learning to which he was now exposed were new and exciting. He enjoyed learning about fluids as he had never learned about this before. Another student mentioned: "What we are doing now in [the STOp], I think we need it in the future. We need to learn *how*…because we do works, we learn new things, work in groups" (Tarik, personal communication, 2016). Tarik expressed how the combination of working together, participating in activities, and acquiring new content knowledge is exciting.

Opportunities for *collaboration and teamwork* overlap in students' joy in the activities because it helps students to engage with the content through their PLNs autonomously. During the interviews, one of the students who had developed fluency by grade eight was able to reflect back on her experience as an ELL while being a longitudinal participant in the case study. She discussed how, "… in grade 8 we got more of group work" (Octavia, personal communication, 2016). Later in the interview, Octavia noted: "[U]sually when kids who are learning English at

the time, they're sometimes embarrassed to ask about words, because how can you not know this word and stuff like that. (Interview, 2016). Therefore, in supporting interest in STEM, students want to engage within their PLNs. The multi-thematic nature of these interview responses indicates that the hands-on learning supports multiple learning needs for ELLs. The activities are inherently differentiated and can maintain ELL participants' interest in STEM because they provide students with what they need to learn.

5.1.3.2 #8 Have [STOp] workshops encouraged you to be interested in science, technology, engineering, and/ or math (STEM) either in school or outside of school? If so, how? All participants (n=8) indicated that STOp workshops had a positive impact on their interest in STEM subjects. Themes that emerged include: *(a) fun and enjoyable experience learning STEM; (b) exploration of STEM; (c) provoking curiosity and problem-solving; (d) interest; and (e) ease of learning* (Figure 22).
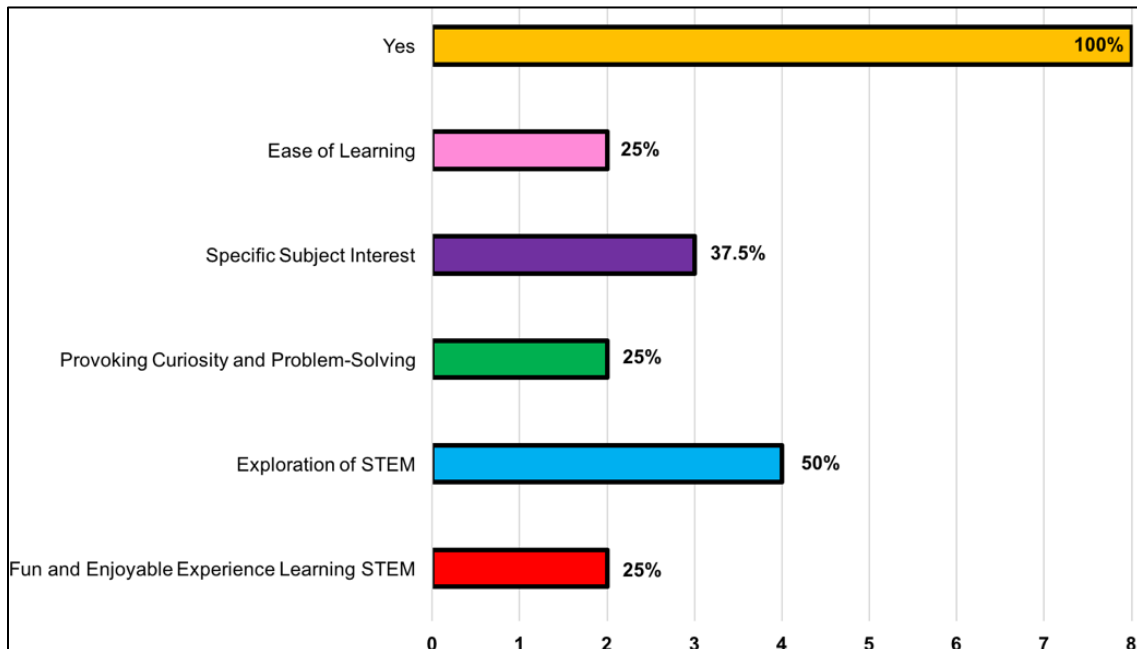

Figure 22. Themes highlighting ELLs' personal STEM interest

The most influential support for maintaining interest in STEM was the exploratory nature of the workshops, accounting for 50 percent (n=4) of the respondents. Students who acknowledged the opportunity to explore STEM would frequently discuss autonomy in their learning as well as additional listed themes. One student expressed:

It makes me to do something like what [STOp] did. Like to make me do something at home, something that I don't know before, like to build a bridge when we were working at the class. Build a bridge, then I went home, and I was asking my brothers about it, and they know how to build it, and then we built it at home, and it was ... I showed them how did we build it at the school [STOp] and then I went home and showed them how to build it, and they knows everything. Like they knows how to build it, and I asked them how do you know, and they told me "we've know it before". (Ibrahim, personal communication, 2016)

This anecdote demonstrates Ibrahim's autonomy in fostering his curiosity with STEM concepts. Another student reflected on their experience and the opportunity to explore and foster interest by stating that:

[STOp] make me like to do science more. It makes me feel that science is more fun than just sitting and doing things. So, we do things. Learn new things … it makes me like the science because we learn new things … Like in my country I was really good in science. Full marks every time. [*Q: But [STOp] made you kind of enlightened as to the hands-on part?*] Yeah, when we do things. (Tarik, personal communication, 2016)

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For Tarik, the opportunity to explore STEM hands-on altered his perceptions of STEM. Acquiring knowledge with ease makes a difference for ELLs because it allows them to evaluate their interest in the topics.

Twenty-five percent (n=2) of the students mentioned that STOp workshops were *fun and enjoyable* while supporting *problem-solving, ease of learning*, and *provoking curiosity*. Participants' responses ranged in complexity with monothematic responses such as "Yes. We have to find out the answers and so then we do different ways to find out ... it's like doing math. Finding different ways to find the answer" (Salim, personal communication, 2016) to more complex ones such as how Salim's response explains how the workshop provoked ELL students' curiosity and problem-solving. Additionally, some responses were more complex and multi-thematic: "Yeah, math. I like the triangle ... how I say it ... the triangle, the circle, all the thinking the math, I like it. I am understanding because I take it before. It's so easy for me" (Cantara, personal communication, 2016).

Interviews confirm that the workshops supported a positive attitude towards and an interest in STEM through hands-on learning. Hands-on learning is naturally differentiated to support a range of needs. These needs include supporting the students' curiosity, bypassing the language barrier, allowing navigation within PLNs, and giving students autonomy over STEM and language learning. As a result, the workshops supported ELLs in both language and STEM. Below is a list of key findings from the interviews.

Summary of attitude and interest key findings from the interviews

- Hands-on learning continued to be the most significant component in supporting interest in STEM for ELLs;
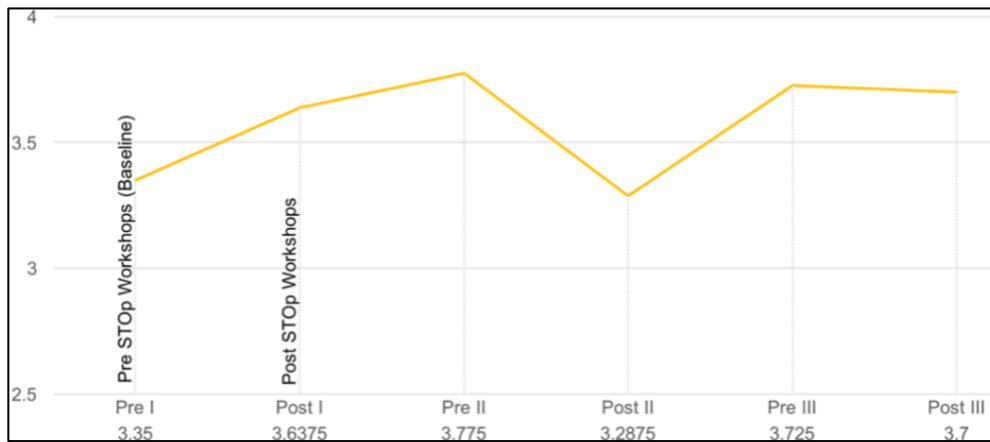
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- the interviews aimed to expose the specific elements that the hands-on learning brought to ELLs STEM learning experiences;

- access to knowledge and acquiring new information was a positive aspect of engaging in the STOp workshops;

- students ultimately wanted learner autonomy which the hands-on activities provide;

- students could navigate within their PLNs;

- the hands-on learning approach was an easy and fun way for ELLs to acquire knowledge while not relying on their second language;

- students could explore and provoke their STEM curiosity – this sometimes led to students investigating STEM concepts from the STOp on their own time and sharing knowledge with their families/ peers.

5.2 Self-Efficacy in STEM and SLA

Social context heavily influences self-efficacy and identity in both language and STEM learning. Students' beliefs about themselves affect their engagement with knowledge and within social groups. Therefore, self-efficacy itself cannot be analyzed without mention of interactions. For ELLs, this is shaped by how they communicate and interact with their peers. This section presents the data from participants' discussion and articulation of their ability to engage in STEM education in their second language. It compares educational models and pedagogies with each other, as well as the role of interactions as the ELLs learned STEM content. Furthermore, it considers how the workshops can support ELLs' self-efficacy in STEM and SLA.

5.2.1 S-STEM survey: measures of self-efficacy in STEM. Understanding of students' perceptions of themselves as participants in the STEM disciplines is essential for keeping ELLs

in STEM. Additionally, ELLs' formation of self-efficacy becomes more complicated when language identity taken into account. ELLs navigate through a myriad of cultural perceptions and interactions to establish their perceptions of themselves as learners of an additional language as well as STEM learners. The S-STEM survey asks a variety of questions probing student self-efficacy in STEM subjects. Although the S-STEM survey mainly analyzes STEM self-efficacy, the section exploring 21st century skills showcases data from ELLs as participants within social learning networks. Exploration of STEM self-efficacy isolates each discipline. Figures 23a, b, and c illustrate the mean averages over time for ELLs self-efficacy in STEM disciplines.

	Pre I	Post I	Pre II	Post II	Pre III	Post III
	3.35	3.6375	3.775	3.2875	3.725	3.7

a) Self-efficacy in engineering and technology over time

	Pre I	Post I	Pre II	Post II	Pre III	Post III
	3.275	3.3875	3.8375	3.70625	3.9	3.55
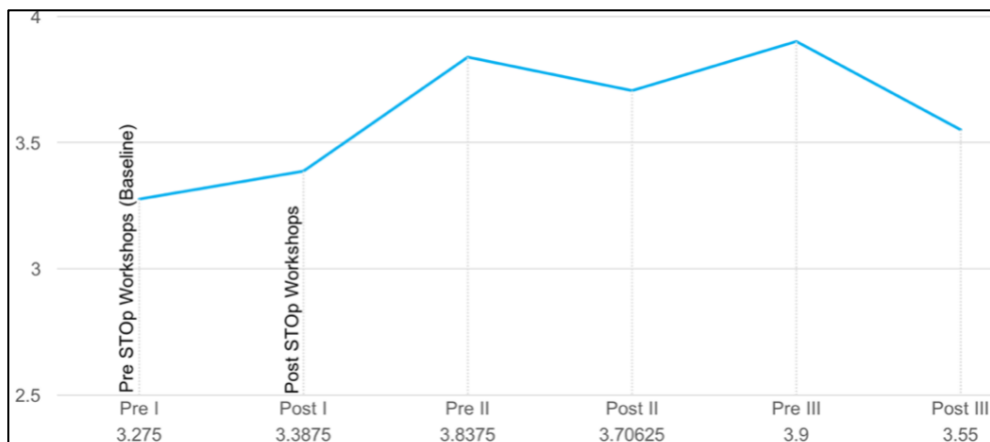
b) Self-efficacy in mathematics over time
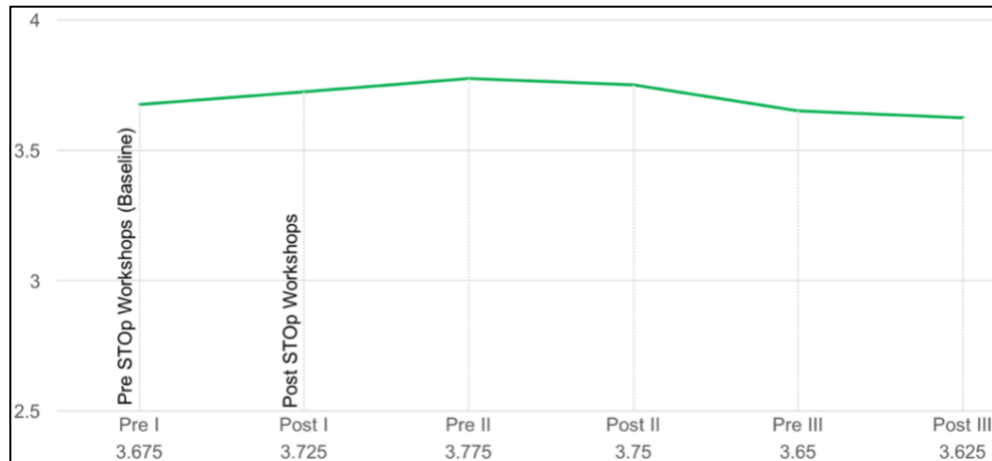
c) Self-efficacy in science over time

Figure 23. Pre-/ post S-STEM mean averages depicting self-efficacy in individual STEM subjects across the longitudinal study.

During Phase I, self-efficacy in *engineering and technology* (Figure 23a) increased. Understanding and self-efficacy in engineering can be attributed to a variety of influencers. During Phase I, the pre-S-STEM survey asked students: *"Do you know any adults who work as engineers?"*. Fifty percent of case study participants indicated that they knew adults who worked as engineers. When students were asked about various STEM careers in the post S-STEM survey, on a 4-point scale, students averaged 2.75 in terms of their interest in an engineering career. During Phase II, the pre-S-STEM survey results show an increase in self-efficacy in engineering before a significant decline in the post-survey. During Phase II, self-efficacy in engineering decreased. However, by grade eight during pre-Phase III, self-efficacy in engineering increased significantly. Then, it became more level by post Phase III.

Self-efficacy in *mathematics* (Figure 23b) increased over time. During Phase I, when ELLs were lowest in language ability, self-efficacy in math slightly increased. Self-efficacy in mathematics continued to increase significantly by pre-Phase II. During post-Phase II, self-efficacy in mathematics slightly declined then increased again during pre-Phase III where it again, insignificantly decreased by the end of grade eight. The level of self-efficacy in

mathematics following the workshops is higher than at the time of the initial survey representing baseline data in pre-Phase I. Although there were students who may have had learning gaps, many quickly gained confidence as it is less difficult to transition between languages when it comes to core concepts in mathematics. Thus, ELL students tend to have enhanced self-efficacy in mathematics in comparison to other disciplines which rely more on knowledge of the English language.

Finally, self-efficacy in *science* (Figure 23c) shows no significant changes over time. Self-efficacy is consistent from the beginning of grade six to the end of grade eight. Although interest insignificantly declined, the fact that self-efficacy remained stable and high is a positive result. As previously mentioned, between grade six and eight Ontario's science and technology curriculum transitions towards more abstract science concepts. If students are still able to maintain their self-efficacy in science, even if interest temporarily declines, there is a greater potential for ELL student interest in science to return by the time they are in grade ten and make the decision whether to pursue higher level science courses in grade eleven.

Although there is a variety of factors that affect self-efficacy, isolating the potential impact of the workshop is important. For example, exploration of the ways in which pedagogies, such as working in their PLNs and hands-on learning, can influence ELLs perceptions of themselves as participants and learners in STEM is warranted. The post S-STEM survey asked students to respond to the following prompt: *"[STOp] workshops have made me more confident in my ability to do science, technology, engineering and/or math."* Data presented in Figure 24 shows that, over time, there is a significant increase in ELL confidence in STEM that can be attributed to participation in STOp workshops.
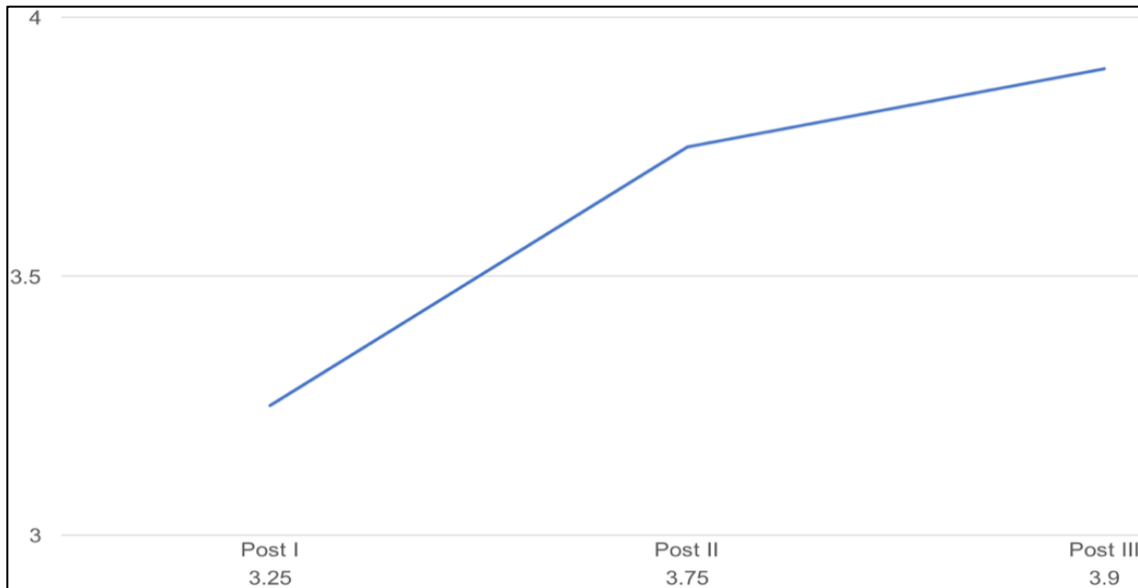
Figure 24. Post-S-STEM mean averages depicting the impact of STOp on ELL self-efficacy in STEM across the longitudinal study.

The concept of 21ˢᵗ century skills is an important component of STEM education. For ELLs, 21ˢᵗ century skills affect STEM content acquisition and self-efficacy, as well as the SLA process. The S-STEM survey asks a variety of questions that probe student self-efficacy within the four C's: creativity, collaboration, communication and critical thinking (Partnership for 21st Century Learning, 2014). *Collaboration* and *communication* are significant for ELLs as they establish themselves within a community of learners who speak the language they are trying to acquire, while also learning STEM, ELLs establish PLNs which is important in fostering a positive attitude towards and an interest in STEM subjects. PLNs also promote self-efficacy in STEM as learning is a social process. If students are uncomfortable collaborating and communicating with their peers while learning English, self-efficacy in both SLA and STEM can be impacted. Responses to questions exploring collaboration and communication (see section 4.3.1) show an average of ELLs self-efficacy in communicating and collaborating with their peers while learning the language over time (Figure 25).
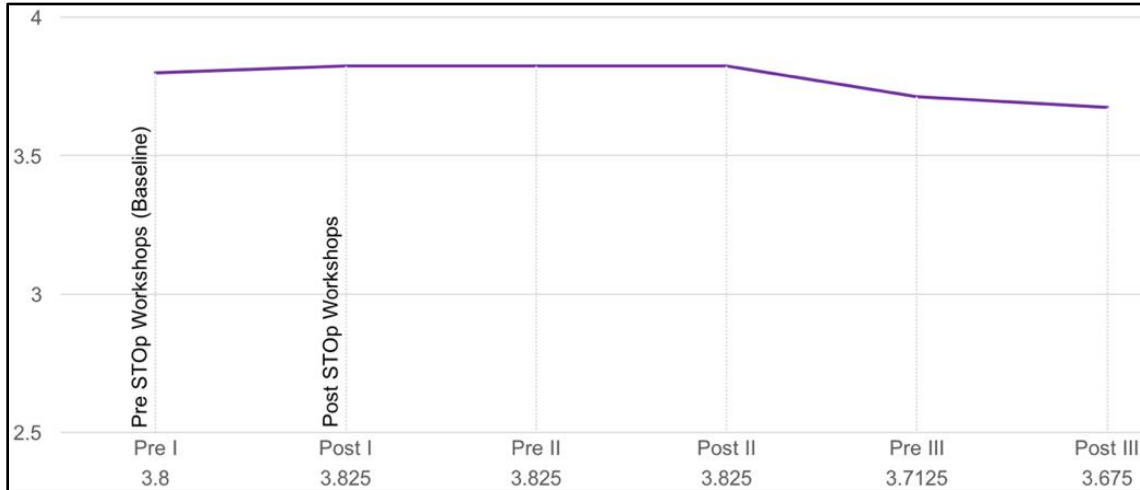
Figure 25. Self-efficacy in collaboration and communication

ELL perceptions of personal leadership, collaboration and communication sustained over time. Students are confident that while learning English, they can support their peers in accomplishing a learning goal. Below is a list of key findings from the S-STEM survey.

Summary of self-efficacy key findings from S-STEM survey

- Self-efficacy in mathematics, engineering, and technology goes up over time;

- Self-efficacy in science sustains over time;

- In isolation, the STOp workshops support self-efficacy in STEM over time; and,

- Self-efficacy as members of the learning community supporting 21st century skills such as communication and collaboration sustains over time for ELLs.

5.2.2 Interviews: personal reflections on language and STEM. Throughout the data, ELLs express the importance of working with their friends. ELLs' PLNs impact self-efficacy in both STEM and SLA because ELLs tap into their peers' skills to assist them in learning English and STEM concurrently. During the interviews, students reflected on how learning through hands-on methods with their peers encouraged inquiry and supported their perceptions of themselves in STEM. The questions explored in this section include: *#3 How did you feel when*

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you were doing the workshops?; #12 Can you tell me who you worked with during the

workshops?. These questions address personal perceptions of STEM and SLA and the impact of

self-designed peer learning networks in supporting the learning process for ELLs.

5.2.2.1 #3 How did you feel when you were doing the workshops? During analysis,

two components emerged. First, students addressed the emotional impact of engaging in the

workshop and described their feelings while participating in the workshops. These emotional

responses reflected on the process of learning STEM while also developing their language.

Responses were coded as: *(a) positive emotions; (b) mixed emotions (positive/ negative); and (c)*

negative emotions (Figure 26).
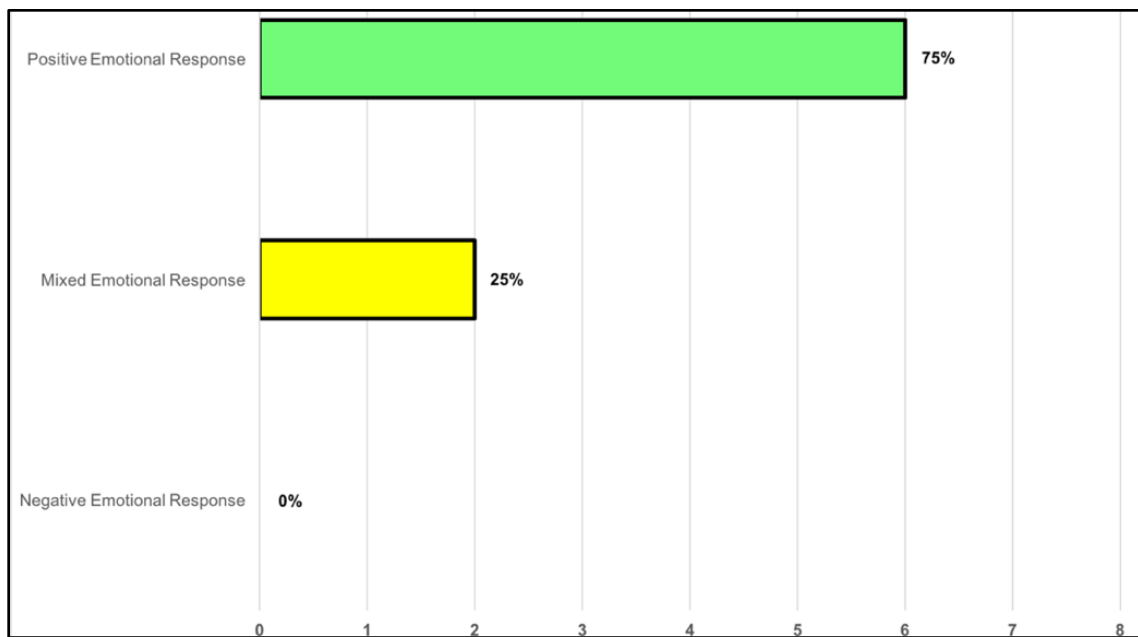
Figure 26. ELLs' feelings towards STOp workshops (emotional response)

Of the interviewed participants, none expressed negative emotions while taking part in

the workshop. Twenty-five percent (n=2) of participants had mixed emotions and indicated that

over time they developed more positive feelings and confidence in the workshops as their

language developed. Additionally, some felt they were nervous until recognizing that they had

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the opportunity to work with friends. By the final phase of the project, students were more confident in their ability to participate in the workshops. Cantara expressed how she was nervous at first because she had difficulty in keeping up with the language, however, after realizing she could work with her peers, she reflected on the workshops more positively (Interview, 2016). Similarly, Octavia stated:

Octavia: [During Phase I] Some of the activities were kind of boring in a way. I didn't really enjoy it. That's pretty much it.

Interviewer: Do you think your language got in the way?

O: No, no, no.

I: What about now, how do you feel?

O: Yeah, it's much more fun. Like recently we just built a bridge for one of our science workshops and it was really fun working together with my classmates to build it. So yeah. (Octavia, personal communication, 2016)

Octavia expressed how the language did not interfere with her learning and that when she had the opportunity to work with her peers, it supported her confidence in STEM. While discussing what the STOp can do to improve their workshops for students who are learning English, Octavia suggested, "For kids who are learning the language at that time, I think more hands-on work with our other groups instead of independent work where they had to read stuff" (Octavia, personal communication, 2016). In supporting self-efficacy in STEM during the process of SLA, students need to collaborate with their peers as resources, both linguistically and academically, to eliminate anxiety surrounding language while learning. Most responses were positive as 75 percent (n=6) of participants reflected on the pride and encouragement felt, as well as the development of their STEM and SLA self-efficacy, from participating in the workshops. Specific

feelings expressed during the interviews include: "Feel good and interesting. Good" (Malik, personal communication, 2016), "Yes, I understand. [*How did you feel?]* Good" (Sabir, personal communication, 2016). Although some students were explicit regarding their feelings, most of the positive feelings were reflected as the students explained the experience with enthusiasm.

In describing components of the workshop that supported a positive learning experience as well as ELL self-efficacy in STEM and SLA, the following themes emerged: *(a) easy learning experience; (b) fun and enjoyable learning experience; (c) peer learning networks; and (d) hands-on learning* (Figure 27).
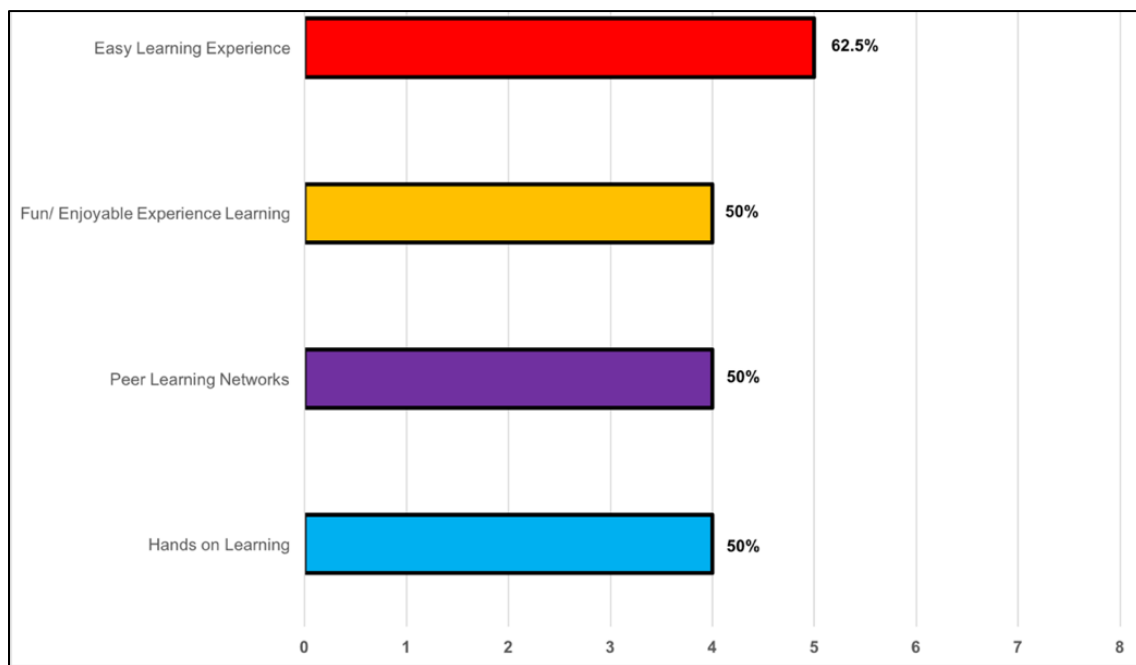
Figure 27. Themes highlighting how STOp workshops supported ELLs' self-efficacy in STEM and SLA

Sixty-three percent (n=5) of students discussed how hands-on learning used by STOp supported their self-efficacy. The relationship between access to content knowledge and later, PLNs, supported ELLs' confidence as they could *do* STEM and practice their second language. Furthermore, there is a sense of autonomy in the workshop learning model which helped

eliminate nervousness or embarrassment. One student commented on how, "[the activities are] much better for me to understand than just explaining. *[Because you could see what you're doing, the hands-on activities? That helps you understand?]* Yeah. It makes me much more clear, like what I'm doing." (Salim, personal communication, 2016).

The responses from interview question #3 were isolated in NVivo and a word frequency query was executed. The word cloud shows that "understand" was tied with "fun" for the second highest frequency (Figure 28).
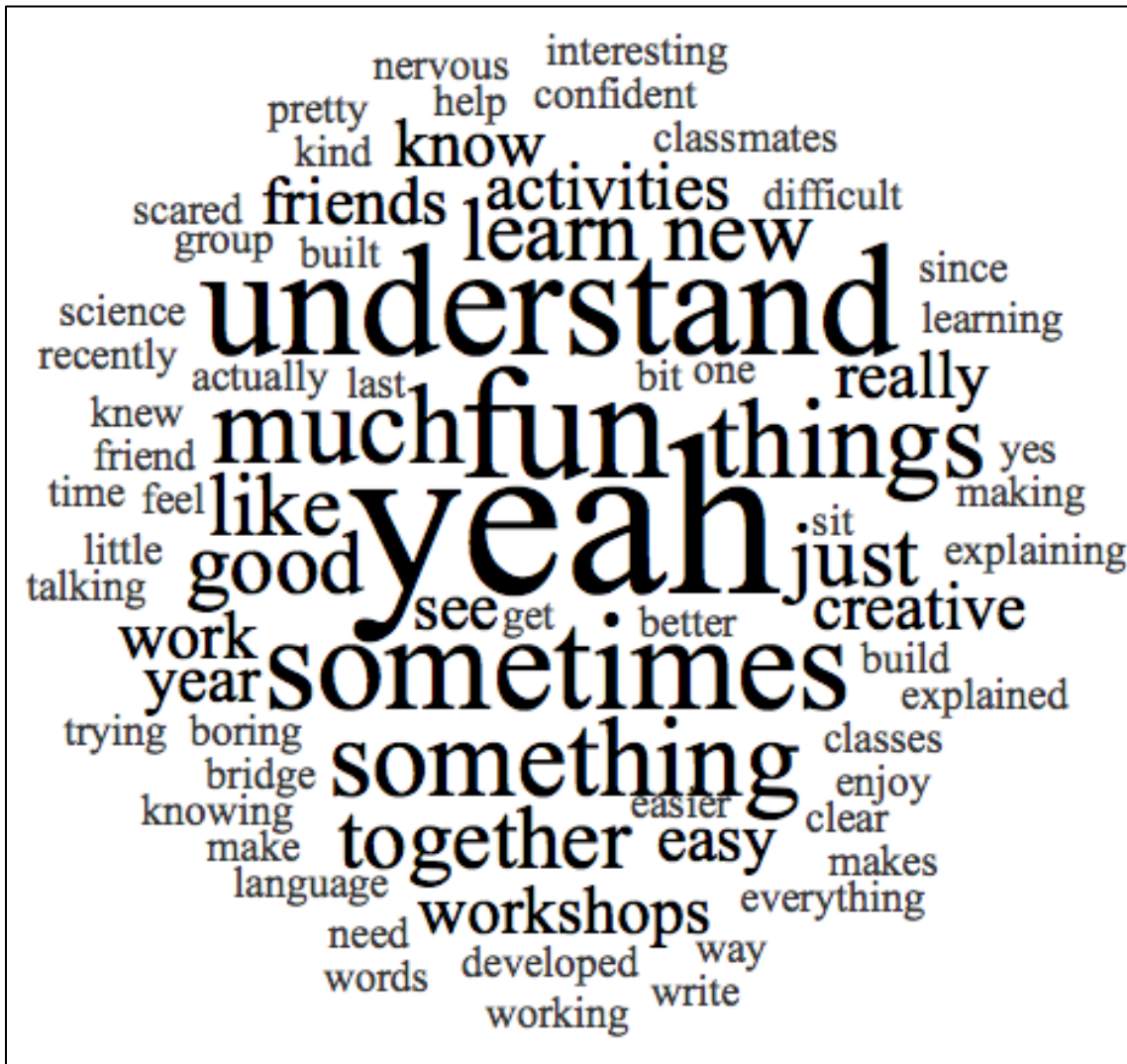
Figure 28. Word cloud exploring self-efficacy from STOp workshops

The word *understand* was then isolated to create a word tree which displays the use of the word by the participants (Figure 29).

Figure 29. Word tree exploring use of the word *understand* in respose to how ELLs felt during STOp workshops

Students felt they could do STEM when they could make sense of the content being presented through the hands-on learning and while working with their PLNs. Another student commented that, "Yes, I understand. [*How did you feel?*] Good… [*Were you confident that you could do the activities?*] Yeah. Sometimes my friend explained to me and I understand some words" (Sabir, personal communication, 2016). In this statement, Sabir was not only able to comprehend the content through the activities, but also acquire STEM language by participating in the activities. Students take ownership of their learning and they tap into various experts within their PLNs while not having to rely on English, thus improving self-efficacy in both STEM and SLA.

Fifty percent (n= 4) of the participants described the workshops as fun. The joyful experience of participating in a low-anxiety and high-motivation hands-on group learning environment supported ELLs' self-efficacy in STEM. The NVivo analysis tied the word *fun* with *understand* in terms of frequency – although the percentage of students describing understanding was slightly higher. The word tree for the word "fun" (Figure 30) contextualizes the ELLs' responses in which they express how pleasant their learning experience with STOp was.
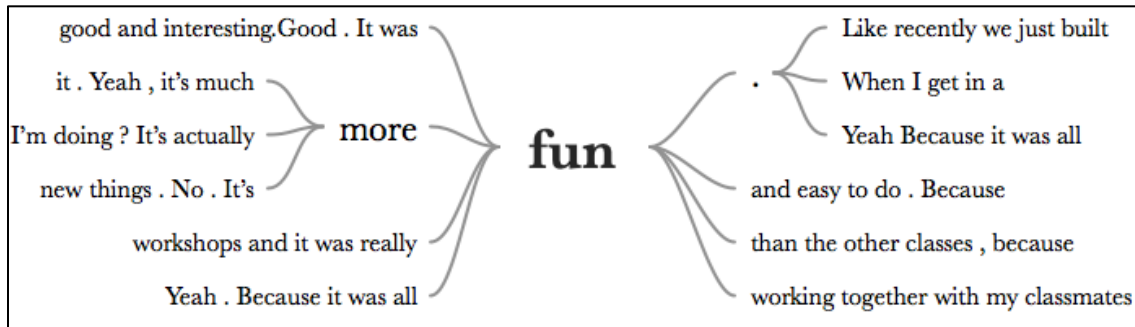
Figure 30. Word tree exploring use of the word *fun* in respose to how ELLs felt during STOp workshops

Students experienced the workshops as fun and enjoyable because they were able to interact with others and participate in hands-on activities. During an interview, one student compared the workshop model in supporting their self-efficacy to traditional classroom instruction. This student stated: "It's actually more fun than the other classes, because we do things" (Tarik, personal communication, 2016). Making the connection between interacting with his PLN and working together to problem-solve and learn using hands-on activities helped the student to be more confident in his perceptions of himself as both a STEM and language learner. Another student noted: "[*Did you feel good doing it?*] Yeah. Because it was all fun and easy to do. Because we need to be creative" (Eesha, personal communication, 2016). Eesha was the only one to mention the word *creative*; however, there is a trend associating *fun* with the design process in hands-on activities. Students discussed building and creating as being a *fun* element of the workshops which can potentially enhance self-efficacy in STEM.

Peer learning networks (PLNs) were discussed by fifty percent (n=4) of the participants. They explained how being able to work with their peers supported their self-efficacy both in language and STEM. Students preferred to network in their peer groups because some ELLs felt uncomfortable approaching adults. Two words that support PLNs in the self-efficacy word cloud (Figure 28) are *friends* (Figure 31) and *together* (Figure 32).

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Figure 31. Word tree exploring use of the word *friends* in respose to how ELLs felt during STOp workshops

When students reflected on the experience of working with their friends, they often used the possessive pronun *my*. This illustrates ELLs' sense of autonomy and ownership in creating their PLNs. When discussing how emotions and self-efficacy were fostered because of interacting with his peers, Tarik states: "When I get in a group with my friends and we work together. I did understand everything" (Interview, 2016). Students were confident when they had the language resources necessary to engage with STEM content autonomously. Cantara offered the following reflection: "I'm scared because sometimes I don't understand their talking and my friends help me" (Interview, 2016). Although there was some discomfort in navigating the lecturing model associated with the workshops, Cantara felt more confident when she had her friends available to assist with language and explain STEM concepts to her in a way that made sense.

The word *together* (Figure 32) embodied a more collaborative lens to accomplish a task while learning STEM content.

Figure 32. Word tree exploring use of the word *together* in respose to how ELLs felt during STOp workshops

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Students indicated that when they could collaborate on a task and maneuver through various roles of leadership, and they felt more positive about their role as a learner of STEM and English. One student noted: "It was really fun working together with my classmates to build" (Octavia, personal communication, 2016). PLNs support self-efficacy because learning becomes collaborative.

Finally, fifty percent (n=4) of the participants found hands-on learning supportive of their self-efficacy in both STEM and SLA. Students used words such as *build*, *do*, and *activities* to describe the impact of hands-on pedagogy on their self-efficacy. One student discussed the process of hands-on learning in supporting their self-efficacy during the interview: "Since I can see ... there's something to do. I can see it" (Salim, personal communication, 2016). Salim indicated that because he can see what he is doing, he can see how to apply the STEM concepts in real life. Another student commented: "I'm doing something new" (Tarik, personal communication, 2016).This statement points to the student's recognition of the playful nature of exploring STEM using concrete materials. The hands-on learning provides students with opportunities to learn and explore both language and concepts together. It creates a low-anxiety and high-motivation learning environment. Such an environment is an integral component of learning language from applied linguistics. It is equally critical in supporting STEM learning.

5.2.2.2 #12 Can you tell me who you worked with during the workshops? Students were asked about the group dynamics and participation as they described their PLNs and how they navigated between language and content. When analyzing this interview question, three themes emerged: *(a) supporting language acquisition; (b) supporting STEM content acquisition; and (c) independent of PLNs* (Figure 33).
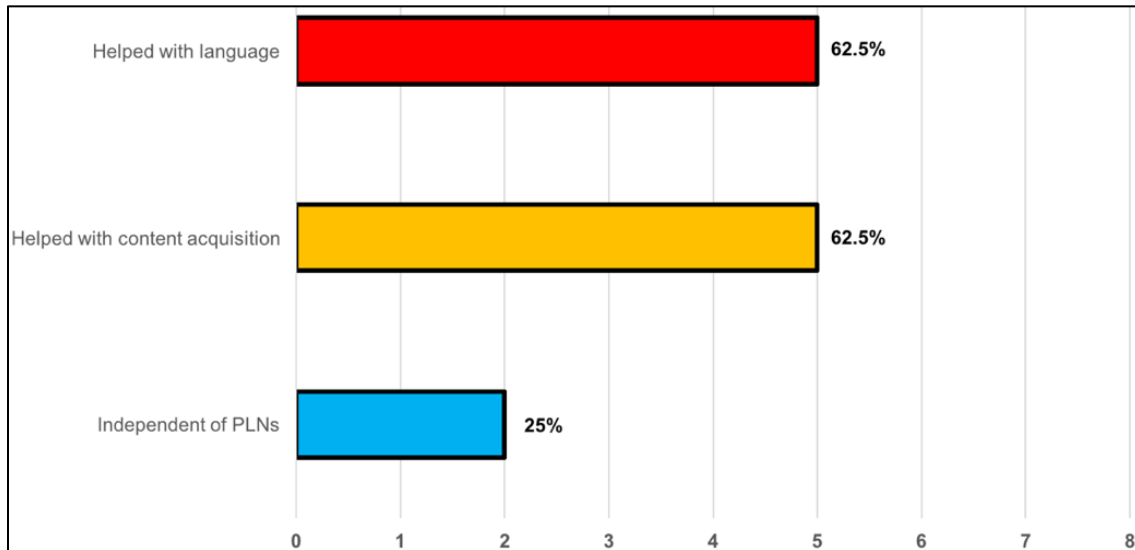
Figure 33. Themes highlighting how PLNs supported ELLs' self-efficacy in STEM and SLA

Assistance with language and content acquisition was discussed equally between 62.5 percent (n=5) of ELL participants. Often, students described linguistic and academic support together. One participant described both components of support in terms of working in her PLN:

Eesha: [I worked] with my group members?

Interviewer: Did any of your group members speak Arabic?

E: Yeah.

I: Did they help translate it for you if you didn't understand?

E: Yeah. They were talking and they were talking about how to do it and they were trying and ...

I: And kind of showed you? Did you learn some English when you were doing the workshops?

E: Yeah, I think.

I: Did they help you learn some of the English words?

E: Yeah. When they were explaining it, they were saying the new words.

I: And when they were explaining and showing it, it made more sense?

E: Yeah. (Eesha, personal communication, 2016)

During this conversation, Eesha uncovers the importance of translating so she can understand and participate in the workshop and acquire STEM language, demonstrating a relationship between content and communication. Similarly, another student reflected on his language learning:

Sabir: I need more language speaking English than I understand.

Interviewer: But when you did run into problems, what did you do? You went and talked to your friends and they translated for you?

S: Yes.

I: What about doing the activities, did they help you learn science?

S: Yes. They explained to me.

Translator: [His friends] helped him with English. They explained to him what it means and yeah, they helped him with the words. (Sabir, personal communication, 2016)

Although the activities did not rely on linguistic communication to acquire STEM knowledge, students were still inclined to learn the language and acquire STEM vocabulary, while also participating in problem-solving and application of STEM content knowledge. The combination of STEM hands-on activities with access to PLNs established by the ELLs fostered self-efficacy. Rarely are PLNs soley focused on either STEM content or language acquisition; instead, students maneuvered between both. Another participant, Malik, explained how he used the workshops to

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develop his conversational language while participating as a STEM learner in the following excerpt:

> Malik: We had a group, my friends.
>
> Interviewer: Did any of your friends speak the same language as you, Arabic?
>
> M: No.
>
> I: You worked in English the whole time?
>
> M: Yes.
>
> I: What did you do when you came into some difficulties?
>
> M: I asked a friend in another group who spoke Arabic. I am in a different group.
>
> (Interview, 2016)

Malik described how he did not work directly with his Arabic-speaking peer, but knew where they were in another group in case he needed translation support or content understanding. By Phase III, Malik felt he could collaborate with his English-speaking peers and have support available if needed.

Most students discussed their PLNs in terms of the relationship between content and language acquisition. However, 25 percent (n=2) of participants indicated that they worked independent of their PLNs. This could be due to a variety of factors. For example, Octavia did not have access to a bilingual peer to support her, but the mix of hands-on learning and working in a group may have familiarized Octavia with STEM. Octavia noted: "There was nobody that spoke my language. [But,] I was pretty confident" (Interview, 2016). Another student stated: "My friends. One of my friends speaks Malayalam, just the same as me. [*However*,] I was

comfortable." (Salim, personal communication, 2016). Salim did not feel he needed his friend but knew that that member of his PLN was available. Overall, who the students worked with and the networks they established helped them learn and supported their self-efficacy in learning the language and learning STEM content. Additionally, providing learning opportunities where students can familiarize themselves with STEM while still empowering students to use their L2 establishes these students as capable learners. This enhances their self-efficacy which opens the door for learning and establishing interest in STEM subjects. Below is a list of key findings from the interviews.

Summary of self-efficacy key findings from interviews

- The workshops provide easy and fun hands-on learning experiences where students have access to their PLNs which in turn, support self-efficacy in both STEM and SLA;

- ELLs express the importance of collaboration for understanding STEM content as well as developing their language;

- the relationship between PLNs decoding, translating and supporting STEM language as well as STEM content in concurrent;

- the workshop model is naturally UDL which builds student confidence as learners and as participants in their learning community; and,

- in situations where there was not another student who spoke the same language as the ELL, they were still able to understand and familiarize themselves with STEM due to the hands-on learning as well as collaboration.

5.3 Chapter Summary

The data that I explore in this thesis reveals the complex relationships between attitude towards and interest in STEM, as well as self-efficacy in both STEM and SLA. The workshops used a pedagogical model that provided students with a series of contextual factors that supported their learning on both cognitive and affective levels. Data presented in this chapter highlights unanticipated results of the complexities of the learning process for the ELL case group. The data reinforces the importance of teachers working as facilitators in learning. This contrasts with common reliance on traditional methods for science instruction that place the teachers in a position of power and makes them responsible for bestowing knowledge upon students. For ELLs, these traditional methods are ineffective. Furthermore, segregating ELLs through *ESL classes* and separating them from their PLNs in STEM is not conducive in terms of supporting their perceptions as English and STEM learners. The multifaceted nature of the data exploring attitude, interest, and self-efficacy in STEM and SLA will be discussed in the following chapter.

Chapter 6: Discussion and Conclusions

Analysis of the data that I explore in this thesis demonstrates that supporting ELLs' attitude towards and interest in STEM as well as self-efficacy in STEM and SLA are not mutually exclusive and need to be explored together. This final chapter explores the findings in relation to the research questions:

- Do STEM workshops, as a form of CBI, affect middle school ELLs attitudes and interests in STEM over time?

- Do STEM workshops affect ELLs self-efficacy, in terms of fostering both STEM and L2 identities in middle school students?

In addition to the research questions, this thesis also considers the pedagogical and environmental components that influence these entities, which in turn provide an argument for supporting access to STEM outreach programs, especially for English language learners. After exploring these factors and their relationships, in the last part of this chapter I review limitations of the work, the implications of the research, and areas for future research.

Overall, STEM workshops as a form of CBI enhance middle school ELLs' attitudes towards and interest in STEM over time, as well as their self-efficacy in both STEM and SLA. The analysis of the data reveals that although there was some fluctuation over the course of the longitudinal study, attitudes, interests, and self-efficacy in engineering, technology, and mathematics increased. Interest in science showed a limited decrease at the end of Phase III. However, during the post-Phase III S-STEM survey, interest in science was the highest among the four subjects. Subsequently, self-efficacy in science sustained across the three phases. The results associate attitude, interest, and self-efficacy in STEM and SLA with the following factors, thus coinciding with the integrated STEM learning framework and self-efficacy theory: (a)

hands-on activities; (b) agency by design; and (c) access to peer learning networks. The design of the outreach program allowed the ELL participants to engage with these factors, which created high levels of motivation and a low-anxiety learning environment in which participants could assess and nurture their interest in STEM. These same factors also supported self-efficacy in STEM and SLA, in that the hands-on activities work as mastery experiences leading to performance accomplishments, with access to vicarious experiences and the ability to ease negative emotions with access to PLNs.

6.1 The Role of Hands-On Activities in Supporting ELLs

The data demonstrates that hands-on activities had the strongest and most positive impact on the participants' attitudes and interest in STEM. When framed using situated cognition theory (SitCT), hands-on activities contextualize learning physically, culturally, socially, and linguistically (Brown, Collins & Duguid, 1989). Hands-on activities apply STEM learning in a real-life context that represents the weight in the integrated STEM learning framework (Figure 4). When ELLs applied their learning, they could make sense of the content. Furthermore, the data from the open-ended questions shows that during the first two Phases of the study, when ELLs were at a earlier stage of L2 acquisition, the ability to engage in STEM in an applied context was a pertinent feature (11 percent both Phases) in terms of making the STOp workshops exciting. Another component of hands-on learning was the process of building and creating, depicted as the pulleys in the integrated STEM framework, that is, engineering design, scientific inquiry, technological literacy, and math thinking (Kelley & Knowles, 2016). As the students worked on the hands-on learning activities, they bridged the STEM disciplines and applied the concepts to real life. The transdisciplinary approach to solving problems contextualized learning. In turn, when the ELLs could accomplish these tasks in a less formal environment that was not as

dependent on language, their emotions were at ease, and they felt good when achieving success during mastery experiences.

Although attitude towards and interest in engineering, technology, and mathematics fluctuated, the data shows that specific workshops in which the ELLs participated aligned with their STEM interests. For example, when the emphasis was on engineering concepts, such as in the structures and mechanisms workshop during which students designed, built, and tested bridges made from newspaper, interest in engineering rose substantially. The same trend applies to self-efficacy in engineering, technology, and mathematics and points to the impact of STOp in supporting positive attitudes towards and interest in STEM as well as self-efficacy.

One unexpected finding is the decrease in interest in science by the end of grade eight. The larger longitudinal study also observed this phenomenon across the four schools (DeCoito, 2016). When exploring the grade eight decrease in more detail, there are a couple of factors and suggestions explaining the phenomenon. First, interest was higher when students were asked if hands-on learning experiences increased their interest in science when compared to their overall interest in science. At the same time, data shows no fluctuation in ELL self-efficacy in science. During grades seven and eight, curriculum expectations shifted towards more abstract science content. The findings also revealed that ELLs found the workshop activities fun. It is possible that during the shift towards more abstract science content the need for hands-on activities and situating science content increases.

An important component of analysis of attitude towards and interest in STEM for ELLs is that hands-on learning relies less on language (Lee et al., 2008; Shanahan, Pedretti, DeCoito & Baker, 2011). The data reveals that some ELLs worked in groups that spoke the same L1 and others worked in groups in which members spoke their L2. Nevertheless, these participants had

L1 peer resources if they needed assistance with translation or understanding content. One student did not have access to anyone who spoke the same language that she did, so she worked independently in acquiring the language and learning STEM. By engaging in the hands-on group activities, ELLs not only familiarize themselves with STEM content, but also acquire conversational (BICS) and academic (CALP) language proficiencies. The hands-on learning means that STEM academic language has a context and in turn, ELLs can develop their STEM academic language proficiency. Additionally, because some students chose to work in groups in which members spoke their L2, they socially engaged with one another. This experience fostered their conversational language. With the autonomy and linguistic context offered by hands-on learning experiences, ELLs can decide how they feel about STEM, as well as comfortably explore STEM and acquire language without pressure or emotional arousal. These findings parallel those of Shanahan, Pedretti, DeCoito, and Baker's (2011) study on the impact of scientific workshops on underrepresented students, including ELLs. Their provisional findings showed similar results wherein ELL students found joy in STEM as a result of an outreach project due to opportunities to work in small groups and hands-on learning that contextualized STEM content in addition to promoting language acquisition. STEM learning and language learning effectively merge during hands-on experiences that provide a context for both. Hoffman and Zollman (2016) emphasize the commonalities in blending STEM and language literacy depicted in Table 2. According to the authors, language is supported by "instructional supports for written and spoken language – e.g., intentional student grouping, multiple representations, scaffolding strategies for different tiers of English vocabulary" (p. 84). At the same time, STEM literacy is supported by "appropriate supports for STEM concepts – e.g., hands-on student engagements, multiple representations, scaffolding strategies for STEM-specific vocabulary" (p.

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84). In traditional classroom instruction, ELLs need to comprehend and decode the language to gain access to STEM content whether through textbooks or lectures. Linguistic comprehension becomes a prerequisite for STEM learning in these environments which make developing positive attitudes towards and interest in STEM subjects difficult – especially during the transition towards more abstract science content. Hands-on activities provided by STOp intervened in the decoding process and made it easier for the ELL participants to assess their feelings towards STEM subjects.

6.2 The Role of Agency by Design in Supporting ELLs

Agency by design fosters the mindset of designing, creating, making, and solving problems actively. The approach builds a sense of empowerment in students in that they are the ones problem-solving and contributing, while not expected to passively acquire knowledge through someone, like a teacher for example. Analysis of the STOp outreach program indicates that the method used by STOp (Figure 5) shows a gradual release of responsibility according to Vygotsky's zone of proximal development dedicating much of the time for student-led learning via hands-on activities (Figure 34).
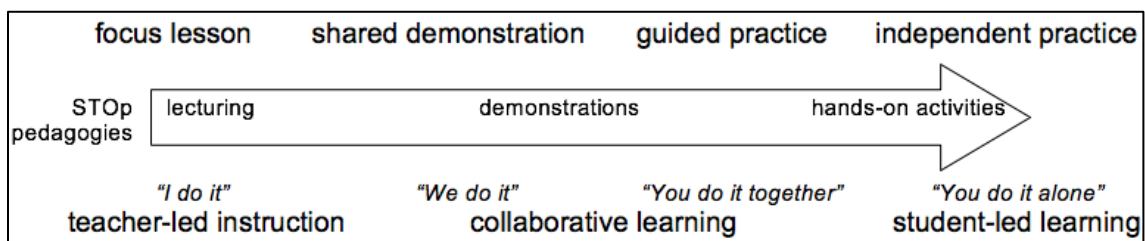

Figure 34. Gradual release of responsibility model of STOp. This figure is adapted to reflect STOp pedagogies resulting from this study's findings from Pearson and Gallagher, 1983, p. 337.

The STOp workshops were guided by curricular topic. However, within that topic they provided opportunities for ELLs to collaboratively create and design. The ELLs included in the sample moved through fluid roles of leadership. Through group choices, ELLs controlled how they engaged with language. Some chose to speak their L1 to design, and others tried to engage in the L2 while having someone close by to support translation as needed. This ability to make the decision eventually leads to autonomy in navigating STEM. Agency by design blurs the lines between supporting attitude and interest as well as self-efficacy. As students engage in hands-on learning, they learn that they can playfully solve problems and create something of value, while enhancing their self-efficacy in STEM. This is reflected in the preliminary findings of maker-centred learning published by Agency by Design (2015) that emphasize the impact of building and tinkering on skill development, as well as development of 21st century skills, including collaboration and communication within a community of learners. The research informing my thesis aligns with the aforementioned findings by Agency by Design in terms of fostering a community of learners and a sense of self in supporting positive attitude and interest as well as enhanced self-efficacy in STEM and SLA for ELLs. Maslyk claims that "the hands-on nature of [STEAM making] work lends itself to true student-centered learning. When students have a choice in what they are working on, engagement is high and students are focused" (2015, p. 14). Through the STOp workshops, students acquire a sense of independence in how they go about participating in STEM and language. This independence is catalytic in developing positive attitudes and interest in STEM subjects as well as overall self-efficacy.

6.3 The Role of Peer Learning Networks (PLNs) in Supporting ELLs

The ability to work with friends had a strong impact on both self-efficacy and fostering positive attitudes towards and interest in STEM. ELLs considered working with their peers to be fun. *People* are a component of agency by design because learning is a social process. Moreover, social context is a major component of SitCT. In the integrated STEM curriculum, people are referred to as a *community of practice* (Lave & Genger, 1991). Social learning contexts are inherent in self-efficacy theory. Working with peers is a common pedagogical strategy used in both content instruction and second language instruction (e.g., when a teacher groups the student with the highest level of expertise and understanding with students who need the most assistance). Findings from this project illustrate peer learning networks (PLNs) as student-centered learning networks designed by the learners that combine and emphasize personal relationships (e.g., friendship) ELLs have with their peers. These networks include students who possess good content knowledge and individuals who have the skills to communicate the content knowledge. When ELLs work with their friends and explore content, the activity in which they are engaged fosters positive attitudes towards and interest in STEM as illustrated in the findings. The fact that in the STOp workshops, ELLs were provided with opportunities to work with their friends made the process of learning fun and enjoyable. This influenced their interest in STEM as well as their engagement in acquiring their BICS and CALP, which in turn impacts ELLs self-efficacy in language acquisition. Similarly, Galda, and Pellegrini (1996) explore the impact of friendship on literacy instruction and find that "close, mutual relationships with friends are often characterized by an emotional climate that supports cognitive development" (p. 3). Like Galda and Pellegrini's study, my study shows that there is an emotional component related to working

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with peers. This has been particularly evident in the interviews in which participants discussed the impact of working with friends on alliveating their nervousness during the workshops. Therefore, having access to PLNs not only makes the learning process more enjoyable, but PLNs also serve as a language and content resource for ELLs that supports attitude and interest through comprehension as well as self-efficacy in both STEM and SLA.

6.4 Limitations

6.4.1 Missing data. A limitation of this study is that because it is a secondary analysis of a larger longitudinal study, there is some missing data from Phase I. Missing students were either absent or may have been scheduled for ESL intervention by the school during data collection. Because we were working as a team of research assistants, some students may not have completed the S-STEM survey at that time. While these gaps do exist, within the case study, the students who participated in the S-STEM survey during Phase I were interviewed at the end of Phase III. As a result, these participants could reflect on their overall experience and discuss the impact of STOp across their middle school experience. In the future, a complete data set could potentially provide more insight in terms of tracking attitude, interest, and self-efficacy in STEM.

6.4.2 Cultural/ linguistic dominance. Another limitation is that Trillium Street School's ELL population speaks predominantly one language – Arabic (Table 3). Only two study participants did not speak Arabic. As a result, my exploration of attitudes, interest, and self-efficacy, is vulnerable to potential cultural dominance. Out of the two participants who communicated in different languages, one, Octavia, spoke Vietnamese according to the demographic information acquired during the interview. By Phase III, both her parents were, however, fluent in English, and she received tutoring outside of school. These experiences

distinguish Octavia from the rest of the case study participants, many of whose parents did not speak fluent English. As a result, it is possible that certain cultural perceptions of schooling and STEM fields may influence this data; however, across the data, hands-on activities, agency by design, and peer learning networks are all elements which support learning, and therefore, based on other literature, these experiences would still support ELLs.

6.4.3 Qualitative design for self-efficacy. Finally, qualitative measures of self-efficacy were not tested between Phases. These emerged during the Phase III interviews. In addition, the S-STEM survey was designed for all students engaging in STEM interventions, not specifically ELLs. Hence, there are no measures for language acquisition between Phases. While these were probed during the interview and ELLs were reminded that they could speak about their whole experience with STOp across middle school, the ability to access data between stages would inform the analysis of self-efficacy in SLA to further support ELLs.

6.5 Implications

Overall, the study has significant implications for educational practice. First, partnerships and collaboration among educational professionals need to be established. Many schools believe in integrating students with learning needs in the classroom with their peers – which is good practice. However, there is a fraction in terms of who is responsible for language and who is responsible for content. Teachers should collaborate with outreach programs because they are able to implement situated learning opportunities that provide ELLs with rich experiences to explore both their linguistic and STEM learning in an easier and less formal context. These experiences support ELLs self-efficacy, attitudes towards and interest in STEM, and language acquisition. They have long term effects on their STEM pathways and their proficiencies in English.

Finally, teachers need support in limiting lecture and textbook-style learning in their science classrooms, especially for ELLs. The study reveals that teachers have a significant influence in supporting ELLs in STEM pathways (Figure 17). By providing ELLs with learning experiences similar to STOp – that is, experiences during which ELLs can engage with their PLNs, agency by design experiences, and hands-on learning – while ELLs are in transition towards more abstract science content can foster positive attitudes and interest as well as self-efficacy in STEM and SLA.

6.6 Areas for Future Research

This study is worth replicating with a larger sample drawn from multiple schools. A larger sample representing a more culturally diverse population would ascertain the validity of my findings. Furthermore, I would consider modifying the S-STEM survey tool for ELLs to incorporate qualitative aspects of SLA and self-efficacy between the Phases in the open-ended questions component in the post-survey. The STEM pathways typology includes three components –attitude towards and interest in STEM by grade eight, access to upper-level science and mathematics courses, and plans to pursue STEM post-secondary pathways (Cannady, Greenwald & Harris, 2014). In response to Cannady, Greenwald and Harris' typology, I would be interested in following up with participants from this ELL cohort through interviews during the other two milestones. In Ontario, secondary school students do not need to enroll in science after grade ten. It would be interesting to obtain the data on the study participants' course selection and discuss their choices with them to see if STOp had an impact, as well as gain access to their grade-twelve Ontario Universities Application Centre (OUAC) to determine whether these students chose STEM post-secondary pathways. Exploring this data over time can reveal the potential long-term impacts of STEM outreach workshops when ELLs are at a

significantly higher level of second language proficiency and able to articulate their experiences using more advanced language.

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Appendix A

Workshop Observation Protocol Sample

STEM Study - Observation Checklist

Date: _____ **School:** _____ **Grade:** _____ **Workshop:** _____

STUDENT ACTIVITIES	YES	NO	TEACHER ACTIVITIES	YES	NO	STOp ACTIVITIES	YES	NO
Group work /Teamwork			Facilitating			Facilitating		
Individual Work			Instructing			Instructing		
Communicating/Discourse			Modelling			Modelling		
Engagement			Integrating STEM Content			Integrating STEM Content		
Problem Solving/ Decision-Making			Assessing			Assessing		
Questioning			Inquiry			Inquiry		
Experiential Learning			21st Century learning			21st Century learning		
Hands-on Learning/Inquiry			Technology Integration			Technology Integration		
21 Century Learning			STEM Career Awareness			STEM Career Awareness		

Observation Notes:

Students:

Teachers:

Workshop Leaders:

Overall Impression of Workshop (in terms of STEM):

Successes:

Challenges:

Recommendations:

Notes:

Appendix B

Phase III - Student Interview Protocol – *Modified ELL Version*

Name: _____ **Grade:** _____ **Date:** _____

School: _____ **Male [ ] Female [ ]**

1. What is the language you speak at home? Does your parent(s) and/ or guardian speak English?

    a. When you have homework, who supports you? How do they support you?

2. Which workshop(s) did you attend this year? Can you describe the workshops?

3. How did you feel when you were doing the workshops? (e.g., confidence, ability, self-efficacy)

4. What do you think was most exciting about [STOp] workshops?

5. Were the STEM activities in the workshop enjoyable? Why or why didn't you find them enjoyable?

6. What could [STOp] do to improve their workshops?

7. Was your ESL teacher present during the workshop? Did you find it challenging? Why? Why not?

8. Have [STOp] workshops encouraged you to be interested in science, technology, engineering, and/ or math (STEM) either in school or outside of school? If so, how?

9. Did you learn any new science, technology, engineering and/or math words during the workshops? Which ones? Can you tell me what they mean? **Offer a paper to the students so they can draw to communicate***

10. Did some words or concepts you learned in science or math class make more sense after the workshop? How? Example.

11. Were you able to understand the workshop leaders' directions? Why or why not?

12. Can you tell me who you worked with during the workshops?

    a. Did your peers help you learn during the workshops? How?

13. Did your teacher help you to clarify concepts learned in the workshop?