

Parental engagement in children's STEM education. Part I: Meta-analysis of the literature

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This paper presents a meta-analysis of the literature on parental engagement with children's formal and informal science, technology, engineering and mathematics (STEM) education. Five recurrent themes have emerged from the literature review: The challenges of supporting parents with children's STEM education; STEM education as a bridge between school and family; STEM education as a gateway for children's future economic success; STEM education as a vehicle for promoting student communication skills; and, the role of hands-on inquiry-based activities in enhancing student engagement. We also outline some international informal STEM education initiatives, their scope, challenges, and impact.

Keywords: formal STEM education, informal STEM education, parental engagement, STEM education, STEM outreach

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1 Introduction

Trying to educate the young without help and support from home is akin to trying to rake leaves in a high wind. (Wolfendale & Morgan, 1992)

The value of parental engagement in children's education is so self-evident that despite the existing literature it is too often overlooked or taken for granted by researchers, educators, and educational administrators (Green, Walker, Hoover-Dempsey, & Sandler, 2007; Hango, 2007; Harris & Goodall, 2008; Let's Talk Science, 2015). And yet, as the literature review below indicates, not all parents possess the necessary knowledge and skills to support their children's education (Ogbu, 1987). Those parents whose support might be the most crucial for the children, i.e., immigrant and minority parents or parents with limited education, too often lack the required knowledge and skills for supporting their children (Suárez-Orozco, 2003). They also experience considerable difficulties in communicating with the teachers and school administrators, thus facing challenges with bridging the home-school gap and learning about their children's educational experiences (Wolfendale & Morgan, 1992). As a result, these families rarely take full advantage of the opportunities offered by their children's schools (formal education) or informal educational opportunities offered outside of school (Bell, Lewenstein, Shouse, & Feder, 2009; Ruiz-Primo,



2011). This especially applies to Science, Technology, Engineering, and Mathematics (STEM) education in the developed countries where a significant percentage of parents have limited STEM knowledge and (or) might hold negative attitudes about STEM (Fine, 1993; Ing, 2014; Kaya & Lundeen, 2010; Let's Talk Science, 2015; Perera, 2014). To exacerbate the problem, a growing number of parents in the developed countries have a limited mastery of the language used in their children's K-12 schooling, thus restricting parents' ability to support their children in meaningful STEM learning (Gibson, 1987).

This paper is the first one in a two-paper series focussing on exploring how parents can be encouraged and supported in engaging with their children's STEM education. The focus on parents and on informal STEM education addresses the need for a comprehensive solution to the problem of student growing STEM disengagement that plagues many modern Western societies (Hathaway & Kallerman, 2012; Let's Talk Science, 2013; OECD, 2016; The National STEM Learning Network, 2017). Therefore, a current literature review coupled with the examination of the worldwide efforts aimed at increasing and supporting parents with their children's STEM education is timely. It sheds light on several relevant international initiatives and highlights research evidence about their effectiveness for increasing student STEM engagement. This study will provide much needed evidence for suggesting viable solutions to educators, educational administrators and community leaders for supporting parents with their children's STEM education that will be relevant to many countries.

Thus, the goal of this paper is to describe the international literature on parental engagement in children's STEM education and to distill major themes that stand out in this ever-growing body of research. The follow-up paper puts these findings into a Canadian context through describing a study that investigated the barriers and catalysts of parental engagement in children's STEM education. As Frank Westheimer, a late Harvard chemistry professor, once noted, "A couple of months in the laboratory can frequently save a couple of hours in the library" (AZquotes, 2018). To the best of our knowledge, there is no recent international study examining the existing literature on parental involvement in children's STEM education. Therefore, an up-to-date examination of the literature is needed as the first step in addressing this problem.

1.1 Motivation for studying parental engagement in children's STEM education

Lately, STEM education has received worldwide attention for economic, social, and political reasons (DeCoito, 2016; The Royal Society Science Policy Centre, 2014; USA National Research Council, 2013). As Rush Holt, the CEO of the American Association for the Advancement of Science, recently noted during the keynote address at the annual meeting of the American Physics Society "Science is not just for scientists" (Gaal, 2017). Although Canadian students have been scoring above average in the Programme for International Student Assessment (PISA) since 2006, their performance in science has not shown any significant improvement and their performance in mathematics has declined over the same period (OECD, 2016). Furthermore, according to PISA, in Canada only half of the top-performing students in science see themselves working in science-related careers (Schmidt & Parkin, 2016). This will clearly not satisfy Canada's need for STEM-oriented workforce if the country is to remain on the forefront of technological innovations (Let's Talk Science, 2013, 2017a).

Similar developments have been taking place for decades in other countries. For example, extensive research evidence shows that in Europe, a large number of STEM professionals are required, but not enough students are interested in pursuing STEM-related careers (European Commission, 2004, 2006; Krapp & Prenzel, 2011; OECD, 2008). Moreover, there is a growing body of research evidence that STEM education at elementary level has a strong impact on the formation of students' attitudes towards STEM-related subjects and consequently on their engagement with STEM (Perera, 2014). For example, according to Zan (2016), the early exposure to STEM is critical for fostering and sustaining student participation, interest and agency in engineering and science. It is also well established that parents play a crucial role in their children's STEM education (Ing, 2014; Perera, 2014). However, to the best of our knowledge, little is known about how to support parents in engaging their elementary-school children with STEM-related activities.

The overarching goal of this study is to learn what motivates parents to engage their children with STEM-related activities and how the parents can be supported during this process. This research explores parental attitudes and responses to STEM-related activities during a public outreach event at the University of British Columbia (UBC), "Family Mathematics and Science Day" (Milner-Bolotin, 2018a; Milner-

Bolotin & Milner, 2017). Family Mathematics and Science Day is an open house annual math and science celebration at the UBC Faculty of Education. This family-oriented event was founded in 2010 and has attracted hundreds of guests from all over the Greater Vancouver Area. More than 50 teacher-candidates participate in it annually. The event's goals are: a) to engage elementary teacher-candidates, many of whom have limited STEM knowledge, in STEM communication to visitors to improve teacher-candidates' attitudes about STEM; b) to model effective STEM outreach for secondary STEM teacher-candidates; c) to build bridges between the Faculty of Education and the community; and d) to engage teacher-candidates, graduate students, and faculty in creating freely available STEM education resources.

1.2 International projects supporting parents with their children's STEM education

In this section, we draw upon some relevant international initiatives aimed at addressing STEM challenges and at encouraging and supporting parents, families and other stakeholders to engage with their children's formal and informal STEM education. Our decision to include these initiatives was based primarily on three factors: the focus of the activities on parental STEM engagement, their location (Canada, USA, UK, and Finland), and the research evidence for their effectiveness. We decided to focus on these four countries for a reason. Being located in Canada, we have extensive experience with the "local" STEM outreach and are aware of the nature of parental involvement in STEM education in Canada and USA (Milner-Bolotin & Johnson, 2017). We also had prior collaboration with our UK colleagues and were aware of similar problems in that country. Thus, it was important for us to explore what had been done to engage parents in children's STEM outreach there. Finally, our decision to include Finland was based on our experience and knowledge of the STEM education initiatives, such as LUMA Centre Finland (LUMA Centre Finland, 2018).

The choice of these countries was also interesting from the perspective of PISA, as Finland and Canada consistently perform significantly above the average, while the other two countries do not (OECD, 2016). In addition, all these countries have a significant number of immigrant families, thus the parents there, might face similar problems with engaging their children in STEM. Finally, we only included the initiatives that have a multi-year history and where some reliable research evidence of their effectiveness has been collected. A brief overview of those initiatives is provided in Table 1. While this list is not an exhaustive one, it shows a range of various

international initiatives aimed at engaging parents in STEM education of their children.

Table 1. Selected International Projects Aimed at Supporting Parents with Children’s STEM Education.

Project (source)	Country	Brief description
Let’s Talk Science (2017a)	Canada	STEM outreach organization; provides materials for students, teachers and parents.
Canada 2067 – The Science of a Successful Tomorrow (Let's Talk Science, 2017a)	Canada	A nationwide project; provides STEM materials for students, teachers and parents.
Family Mathematics and Science Day (Milner-Bolotin & Milner, 2017)	Canada	Annual open house family-oriented event where teacher-candidates from the UBC Faculty of Education engage with STEM activities with the community.
Science & Math Education Videos for All (Milner-Bolotin, 2018b)	Canada	Educational STEM videos of hands-on experiments for teachers, parents and students.
StarT (LUMA, 2017)	Finland	Based at the University of Helsinki, an international network of learning communities promoting STEM education.
Science is for Parents Too (Leach, 2017)	UK	STEM-related courses for parents at the University of York.
The National STEM Learning Network https://www.stem.org.uk/	UK	Comprehensive list of materials and resources for parents, students and educators.
Parent Partners in School Science (PPSS)	USA	NSF-funded project, provides teachers, parents and children from three Philadelphia elementary schools opportunities to engage in STEM-related activities.
English-Spanish Family Guide to Science (AAAS, 2013)	USA	AAAS-NSF-funded English-Spanish bilingual Family Guide to Science.
Equals and Family Math (Lawrence Hall of Science, 2017)	USA	Math courses, workshops and curricular materials for K–12 teachers, parents, families, and community members (English/Spanish).
Family Science (Foundation for Family Science, 2017)	USA	Family-oriented science-related activities (English/Spanish).
Techbridge Girls (Techbridge, 2017)	USA	Science guides for families (English/Spanish/Chinese).

2 Literature review

The importance of meaningful engagement of the next generation of students in

STEM has been discussed widely in Canada and internationally (Bybee, 2013; Let's Talk Science, 2012, 2013, 2017a; USA National Research Council, 2013). Today the value of STEM education has become even higher with the developing countries facing a growing economic divide between the rich and the poor, increasing immigration and economic uncertainty for the new immigrants and for the local population, the lack of qualified STEM professionals, and the growing importance of problem solving and critical thinking skills in the modern society (British Columbia Ministry of Education, 2015; Chachashvili-Bolotin, Milner-Bolotin, & Lissitsa, 2016; DeCoito, 2016; Milner-Bolotin & Johnson, 2017; Ontario Ministry of Education, 2014; The National STEM Learning Network, 2017). At the same time, there is research evidence that families play a crucial role in children's education (Dabney, Tai, & Scott, 2015; Dierking & Falk, 1994; Perera, 2014) and parental engagement in children's STEM education can mediate the negative effective of socio-economic disadvantage (Hango, 2007). Moreover, in the last few decades, there were many new initiatives, some of them are country-wide, that aimed at engaging entire families in STEM (LUMA Centre Finland, 2018; Miller, 2017; Milner-Bolotin & Milner, 2017). However, for this study we decided to limit our search to the peer-reviewed papers published in high-impact journals (or by the notable STEM or STEM-related educational organizations) that specifically focus on different kinds of parental engagement with children's learning in or out of school STEM learning. The papers that were included in this analysis were found through the search in the educational databases such as ERIC and Google Scholar, through the references in the national STEM education documents, as well as the references in the peer-reviewed papers found earlier. While we reviewed hundreds of documents, we have limited this analysis only to the papers that matched our criteria.

In this study, parental engagement entails activities conducted by parents or family members, such as homework support, attending school meetings, volunteering at school, and participating in STEM-related activities in and out of school. Through the analysis of the literature focussed on parental engagement with their children's education, the following five themes have emerged: Parental engagement in children's STEM education; STEM education as a bridge between school and family; STEM education as a gateway for children's future economic success; STEM education as a vehicle for promoting student communication skills; and hands-on inquiry as a vehicle for enhancing student STEM engagement. Below we briefly outline each one of these themes.

2.1 Challenges of supporting parents with children's STEM education

There is a strong consensus amongst researchers about the benefits of parental engagement with their children's education (Barton, Drake, Perez, St Louis, & George, 2004; Green et al., 2007; Harris & Goodall, 2008; Kaya & Lundeen, 2010; Let's Talk Science, 2015; Perera, 2014). Parents have a positive influence on children's motivation to learn and consequently on their academic achievement (Cheung & Pomerantz, 2012; Kuperminc, Darnell, & Alvarez-Jimenez, 2008). In line with that, extensive research evidence indicates that parental involvement has a positive impact on their children's STEM engagement and consequently on their achievement (Ing, 2014; Let's Talk Science, 2015; Perera, 2014).

However, not all parents who want to support their children in STEM education know how to do that (Leach, 2017; Let's Talk Science, 2015). There are at least two reasons for that. First, parents might have limited STEM knowledge relevant to children's school curriculum. Second, some parents, especially immigrant parents, might experience a language barrier, preventing them from supporting their children. This is especially relevant to parents who themselves might have limited (STEM) education or are new to the educational system experienced by their children, such as the parents who are immigrants, foreign workers or international students.

2.1.1 Supporting parents with limited STEM education

Given the importance of parental engagement with their children's STEM education, there have been many attempts by educators in public, private, governmental and non-governmental agencies to create resources for parents. Below we describe three of these initiatives aimed at facilitating parental involvement in their children's STEM education.

Let's Talk Science is a charitable Canadian organization focussing on promoting STEM education and outreach. It provides a comprehensible list of activities to encourage parents to exert a greater influence on their children's STEM education (Let's Talk Science, 2017b). Moreover, a Canadian nationwide project, Canada 2067 – The Science of a Successful Tomorrow (Let's Talk Science, 2017a), has been created to develop an action plan and a national vision for STEM learning. On their official website, there is an entire section devoted to informing parents about how and why they should support their children's STEM education.

Science is for Parents Too is an initiative from the University of York in the UK. In 2013, STEM educators created a set of science courses for parents, who might have limited knowledge, called “Science is for Parents Too” (Leach, 2017). The courses aim at teaching parents the science their children are learning at school. The 2014–2015 course final assessment report indicates an increase in parental knowledge of and confidence about science. It also shows that “[a] greater proportion of children whose parents attended the courses would like to be a scientist after the course compared to the control group” (West, 2015, p. 1).

Science & Math Education Videos for All is a collection of short educational videos relevant to K-12 STEM curriculum showing hands-on experiments that teachers, parents and students can perform at school or at home (Milner-Bolotin, 2018b). These videos are hosted on a YouTube channel. They include STEM experiments, conceptual explanations of the phenomena behind these experiments, and additional resources and activities. The resource was originally created to support future STEM teachers and inspire them to engage their students in STEM in a meaningful way. However, many parents have found it useful as well.

2.1.2 Supporting parents with limited language proficiency

An additional challenge to parental engagement with children’s STEM education in societies with high proportion of immigrants is the language barrier. In the United States, the most spoken unofficial language is Spanish. To facilitate and encourage Spanish-speaking families to engage with science, Partnership for Science Literacy, a project co-funded by the American Association for the Advancement of Science (AAAS) and the National Science Foundation, has published a bilingual English-Spanish Family Guide to Science (AAAS, 2013).

Some other options to Spanish speakers in the USA include: Equals and Family Math, Family Science, and Techbridge Girls. *Equals and Family Math* offers several programs, workshops and curricular materials in mathematics for K–12 teachers, parents, families, and community members at the Lawrence Hall of Science, University of California, Berkeley (Lawrence Hall of Science, 2017). *Family Science* offers online and book activities (Foundation for Family Science, 2017). *Techbridge Girls*, in addition to English, produces science guides in Spanish and Chinese (Techbridge, 2017). Similar efforts are undergoing in other countries.

As mentioned above, supporting parental involvement in their children's STEM education is important to opening future opportunities for the students. It also helps family members to establish a common ground for productive and meaningful interactions through having interesting topics for discussion (Let's Talk Science, 2015). This opens doors for bridging the home-school gap.

2.2 STEM Education: A bridge between school and family

School-related projects, homework assignments, and visits to science centres open additional opportunities for positive STEM-related interactions between children and family members (Rodari, 2009; Vartiainen & Aksela, 2013). Science clubs for children offered outside of school is another example of activities helping engage families in science. According to the study by Vartiainen and Aksela (2013), parents and guardians of the 3–6 year old children who attended the science club at the University of Helsinki wanted to discuss science at home with their families and often brought up the characters from the science activities in the discussions. Moreover, family members of these children have reported that their children's interest towards science was raised as a result.

Given the importance of parental involvement and participation with their children's education, The Franklin Institute (TFI), a major US Science Museum, developed and implemented Parent Partners in School Science (PPSS) (Luke & Foutz, 2007). This project, funded by the National Science Foundation, provided teachers, parents and children from three Philadelphia elementary schools with opportunities for engaging in STEM-related activities at school, at home and in the community. According to McCreedy, and Luke (2006), PPSS was beneficial to children, parents and teachers alike. As a consequence of the initiative, teachers felt more confident and comfortable teaching science and even began teaching it more frequently. Parents, in turn, reported that PPSS's legacy sparked children's interest in science. Parents and teachers felt that their relationship improved because of PPSS.

STEM-related homework assignments are shown to be an inviting way to foster parent-child collaboration and interaction. This facilitates parental engagement with their children's STEM education (Kaya & Lundeen, 2010; Solomon, 2003), thus bridging the home-school gap. Science centres, science museums, botanical gardens, aquariums etc., are venues that provide family members with opportunities that facilitate not only cognitive learning, but also address social and emotional domains

(Briseno-Garzon & Anderson, 2012; Dierking & Falk, 1994; Sanford, 2010). Borun, Chambers and Cleghorn (1996) identified the following behaviours as indicative of family learning in science museums: asking and answering questions, commenting on the museum exhibit, reading exhibit labels silently and aloud, pointing to an exhibit, or even physically interacting with it.

Another venue for bridging the home-school gap is to encourage parents to discuss future career prospects in STEM-related areas with their children (Let's Talk Science, 2015). This is emphasized by STEM educators and outreach organizations as we will show below.

2.3 STEM education: A gateway for children's future economic success

Ample research evidence suggests that many parents want to support their children in STEM studies because STEM-related careers may bring economic opportunities for their children's future prosperity (Ayalon & Yuchtman-Yaar, 2003). For example, Canadian parents see STEM-related careers as attractive prospects for their children, yet only a small percentage of the parents (28 %) actually discusses the value of STEM education with their children (Let's Talk Science, 2015). UNESCO highlights STEM education as a contributing factor for equipping young people for the job market. It states:

All schools and schooling systems accept that part of their role is to prepare children for the world of work, sometimes implicitly and, more and more, explicitly. To achieve this aim, school systems and their stakeholders will see that affective and motivational aspects of science learning are important not only in the classroom, but also in the wider societies. (UNESCO, 2012, p. 12)

STEM education needs to be emphasized to address the shortage of STEM workers in many developed and developing countries. According to BQ portal supported by the German Federal Ministry for Economic Affairs and Energy (2013), many countries, including Germany, USA, Japan and Brazil, are reforming their immigration policies to attract STEM workers. This has become one of the big news items in many countries around the world. According to European Centre for the Development of Vocational Training (Cedefop), STEM professionals are among the top five skill shortage occupations across the European Union (EU) (Cedefop, 2017). According to EU Skills Panorama 2014 Report (ICF and Cedefop, 2014), there was consistent numerical and percentage growth from 2003 to 2013. This growth is expected to continue from 2013 to 2025. "Over one million additional science and engineering jobs are expected to be

created from 2013 to 2025; meaning that, by 2025, science and engineering professionals will comprise 3% of the total EU-28 workforce (7.7 million workers)” (ICF and Cedefop, 2014, p. 2). The 2014 Report states that STEM professionals need a wide range of knowledge and skills including: complex problem solving, judgement and decision making, research skill, mathematics, active learning, listening and comprehension, and communication skills. The latter is, in fact, essential for local and immigrant students and professional, as will be shown below.

2.4 STEM education as a vehicle for promoting student communication skills

Effective STEM education is facilitated in a dialogic environment where learners are encouraged to cooperate with others, state claims, negotiate strategies for problem-solving and come to a consensus. This requires effective communication by educators and learners (DeVries & Zan, 2012; Johnston, 2012; National Research Council, 2012). Communication skills are crucial for students to become proficient STEM learners as they need to ask questions, plan and carry out investigations, analyze and interpret multi-faceted data (e.g., graphs, figures, charts), construct explanations, propose solutions, and engage in evidence-based argumentation (National Research Council, 2012). This is equally true for native and non-native English speakers (Cohen & Urry, 2007; Fawcett & Garton, 2005; Mashburn, Justice, Downer, & Pianta, 2009; Van Meeteren, 2016).

As mentioned earlier, family visits to science centres are great opportunities for emotional, social, and cognitive learning (Suter, 2014). Therefore, children and family members need appropriate language skills to communicate ideas to address emotional, social and cognitive domains. Ash (2004) identified linguistic English-Spanish code-switching among family members during the science-oriented discussions inspired by the family visit to an aquarium in California. For students and parents whose first language is not English, communicating STEM ideas can help them to acquire the English language in a meaningful way (McCreeedy & Luke, 2006; Oliveira & Lan, 2014). This is particularly relevant to countries such as Canada that receive many immigrant and refugee families.

2.5 Hands-on inquiry: A vehicle for enhancing student STEM engagement

In the 20th century, inquiry-based science education was promoted by several influential educators, including Dewey (1938), Schwab (1966), and DeBoer (1991). In contrast to the traditional fact-driven teaching approach, inquiry-based STEM education uses a science method as a key pedagogical strategy. In inquiry-based STEM classrooms, students are asked to pose questions, design experiments, collect, analyze and interpret data, and draw their own conclusions (British Columbia Ministry of Education, 2015). There is ample research evidence that inquiry-based education also promotes parental involvement in both formal (Mousoulides, 2013; Zwiep & Straits, 2013) and informal STEM learning environments (Dabney et al., 2015; Rodari, 2009). This might be one of the reasons why the emphasis on inquiry-based teaching has become a prominent feature of contemporary educational reforms (British Columbia Ministry of Education, 2015; USA National Research Council, 2013).

In addition to inquiry-based activities, demonstrations, and hands-on experiments have shown to be effective ways to reach out to parents and students alike, especially in informal settings, such as STEM centers, museums and public outreach events (Milner-Bolotin, 2011). For example, “Family Mathematics and Science Day” at the University of British Columbia has gathered hundreds of visitors over the years and its success is largely due to well-designed interactive demonstrations through which children and their parents can engage with STEM-related activities (Milner-Bolotin, 2018a; Milner-Bolotin & Milner, 2017). A Canada-wide outreach event – Science Rendezvous– reaches hundreds of thousands of people all across the country in order to engage them in STEM (D. Miller, Miller, Miller, & Bawagan, 2017; K. Miller, 2017). The rapid growth of this event and its spread from the University of Toronto to across Canada over the last decade have highlighted the need for family-oriented STEM outreach and the willingness of parents to engage in it. Hands-on activities have become a prominent feature of contemporary STEM centers, such as science museums, aquariums, and botanical gardens, in order to engage parents and children and facilitate STEM learning.

3 Conclusions

The literature review on parental engagement with their children's STEM education has revealed five recurrent themes. These are: The benefits of parental engagement with their children's STEM education; STEM education as a bridge between school and family; STEM education as a gateway for children's future economic success; STEM education as a vehicle for promoting student communication skills; and, hands-on inquiry as a vehicle for enhancing STEM engagement of both children and their parents.

3.1 The benefits of parental engagement with children's STEM education

There is a strong consensus amongst researchers about the benefits of parental engagement with their children's education in general, and STEM education specifically. Parents have a positive impact on their children's engagement with STEM and consequently on their achievement. However, not all parents who want to support their children know how to do that, mainly due to two reasons. Firstly, parents might have limited STEM knowledge. Secondly, some parents might experience a language barrier, particularly in countries with a large immigrant population. Many international organizations attempted to address those issues by creating family-oriented STEM resources.

3.2 STEM education: A bridge between school and family

School-related projects, homework assignments, out-of-school science clubs and visits to science centres open additional opportunities for positive STEM-related interactions between children and family members. For example, STEM-related homework assignments are shown to be an inviting way to foster parent-child cooperation and collaboration. Apart from providing additional topics for subsequent parent-child conversations at home, science clubs offered outside of school have been reported to motivate young children, raising their interest towards science contents. Moreover, visits to science centres such as science museums, aquariums and botanical gardens allow for opportunities that not only facilitate visitors' science learning, but also address social and emotional domains.

Community projects, in turn, have shown to be beneficial to children, parents, and educators. Teachers reported to be more confident about science teaching and more

open to teaching science in a more interactive way because of their participation in these outreach science projects. Parents also report an improvement in the parent-teacher relationships.

3.3 STEM education: A gateway for children's future economic success

Many parents want to support their children in STEM studies because STEM-related careers may bring economic opportunities for their children's future prosperity. Furthermore, although students from some developed countries, i.e., Canada and Finland, have been performing consistently well in PISA science exams, not enough of those quality students have the intention of pursuing STEM-related carriers. There is an increasing international demand for skilled STEM workers. The shortage of STEM professionals is such that some countries, i.e., Germany, the USA, Brazil and Japan are reforming immigration regulations to attract skilled STEM professionals.

3.4 STEM education: A vehicle for enhancing student communication skills

Meaningful STEM formal and informal activities invite learners to communicate complex and abstract ideas in a written and oral format to a variety of audiences, i.e., teachers, peers and parents. STEM education is facilitated when there are ample opportunities for a dialogue. These opportunities allow for the various steps of the problem-solving process, i.e., asking questions, raising hypotheses, designing experiments, communicating results, and reaching conclusions. To effectively perform in these dialogic constructivist classrooms, learners and teachers alike need a sound mastery of the language. These learning environments can be effective in enhancing communication and linguistic skills for native English speakers and those for whom English is an additional language. Moreover, effective communication is a valuable skill for successful STEM-related careers.

3.5 Hands-on inquiry: A vehicle for enhancing STEM engagement

Inquiry-based STEM education promotes parental involvement in both formal and informal learning environments. Hands-on activities that parents and children can engage with during their visits to STEM centres are now a common feature of most contemporary venues. These are shown to raise visitors' motivation towards STEM-related activities and facilitate learning. These five themes have emerged from the

analysis of many international STEM-related outreach projects described in this paper. In the follow-up paper, we describe a study conducted in the context of the University of British Columbia Family Mathematics and Science Day (Milner-Bolotin & Milner, 2017). We examine how these themes play out in a specific STEM-outreach context. The main aim of the follow-up study is to learn what motivates parents to engage in STEM outreach with their children, how educators can support these parents, and how research can inform STEM outreach efforts.

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