Internalization of STEM Education

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INTRODUCTION

Learning Contexts in Teaching of STEM Disciplines

For many years the need to educate and support our teachers to implement reforms in science and mathematics education has been ongoing throughout the world (National Academies of Sciences, Engineering, and Medicine, 2019; Mundry et al., 2009). In more recent years, this call has extended to include teaching through integrated science, technology, engineering, and mathematics (STEM) subjects as a vehicle to learn disciplinary core ideas, science and engineering practices, and cross-cutting concepts (NGSS Lead States, 2013). It was recognized that these intertwined STEM disciplines have a potential to educate students essential skills like problem solving, critical thinking, and scientific discourse, and become an even more compelling avenues for student development when considered in conjunction (Jang, 2016). Opportunities to engage students in dynamic and cross-curricular ways emerge from the integration of the STEM disciplines.

It has also been recognized that learning through integrated STEM subjects can be a powerful tool to engage students who have traditionally been marginalized (Garibay, 2015). This integration of disciplinary concepts and practices can be implemented in a wide variety of contexts that are rooted in students' experiences, culture, and interests through socioscientific issues and social justice (Rodriguez, 1998; Johnson, Macalalag & Dunphy, 2020). The first section of this book explores two unique contexts in which STEM education is being developed. The first chapter describes the current literature on the application of socioscientific issues to teach STEM in inclusive learning environments. The second chapter describes the development of public residential STEM high schools in Egypt that completely reimagined how STEM is addressed in that country.

The chapter titled "Encouraging STEMpathy: A Review of Literature Addressing STEM Learning for Students with Special Education Services in Inclusive Learning Environments" by Joseph A. Johnson, Michael Zielinski, Jessica N. Essary, Kim Dean, Keri Bartynski, and Augusto Z. Macalalag highlights student centered STEM education, with a socio-scientific focus, in special education settings. The chapter defines technically identified needs (TIN) and discusses the challenges in achieving inclusive education. The chapter shows that inclusive STEM learning with a socio-scientific focus may provide a powerful venue for meeting the needs of students with TINs since socioscientific issues (SSI) can support integrating social emotional learning into STEM content instruction in inclusive settings. The chapter authors call for more research exploring the potential of SSI for engaging students with TINs in STEM and investigation of best practices for integrating SSI for students in inclusive settings.

The chapter titled "STEM Teaching and Learning Model in Egypt: Retrospect and Prospect" describes the process by which nineteen public residential STEM High Schools (grades 10, 11 and 12) were established in Egypt with the goal of revolutionizing STEM education in that country and providing a model for other countries around the world. Reda Abouserie, Zeinab El-Naggar, Hala El-Serafy, Amany Abd El Azi, and F. Joseph Merlino describe these innovative Egyptian STEM high schools as the result of a decade of collaboration between the governments of Egypt and the United States as mediated through the U.S. Agency for International Development (USAID). The chapter describes the many structural barriers faced in attempting to improve the quality of the Egyptian pre-university STEM education and provides insight into the features of STEM public schools unique to Egypt. Finally, this chapter details the STEM Teacher Education and School Strengthening Activity (STESSA) Project, a five-year, USD $24 million contract from USAID-Egypt to support the expansion of the network of STEM high schools across Egypt and to develop five new integrated STEM teacher education programs at undergraduate level and two programs at the graduate level in collaboration with the Ministry of Higher Education and Scientific Research.

STEM Teacher Education

If STEM education is to be effective, teachers must be prepared to successfully implement current and research-based pedagogical practices in their classrooms. Despite the tendency for educators to emulate the practices they experienced as students (Lortie, 2020) and resistance among preservice teachers to ideological and pedagogical changes (Rodriguez & Kitchen, 2004), STEM education can be changed through focused efforts in teacher preparation and professional development programs (Johnson, Macalalag, & Dunphy, 2020). This section explores aspects of teacher professional development in interdisciplinary STEM subjects as well as the motivations for teachers to learn and improve their STEM teaching pedagogy. Specifically, the first chapter illuminates teachers' motivation and practices in STEM implementation. The second chapter describes the demands on and resources for STEM implementations for teachers and the effect these factors have on their job satisfaction. The third chapter in this section explains the analysis of video reflections and personal reflective accounts of a female preservice teacher, exploring self-efficacy, belonging, and identity in learning STEM content through the lens of gender. The final chapter also explores gender as a variable along with problem solving skills to explore the impact of these variables on STEM awareness levels of classroom teachers. These chapters illuminate challenges faced in preparing and developing STEM educators as well as the mindset and motivations of teachers in these fields.

Specifically, Busra Kartal, Tezcan Kartal and Adem Tasdemir investigate and report on "How and Why Teachers Implement STEM? A Journey to Teachers Beliefs and Teaching Practices" using teachers' beliefs, motivational orientations, and STEM integration and implementations as their theoretical frameworks. They used a multiple case study and purposeful sampling to select three female and three male teachers as participants to answer the following research questions: 1) What are participants' beliefs and motivational orientations regarding STEM education? 2) How do participants implement STEM subjects in their teaching practices? Using in-depth semi-structured interviews, their teacher participants described their experiences, espoused beliefs, challenges, and needs in terms of STEM teaching, motivational orientations, and teaching practices. Their research findings suggest that teachers' beliefs about teaching STEM subjects align with student-centered orientations such as encouraging students to work in groups to increase students' participation, motivation, and interest in integrating STEM subjects. Their participants mentioned utilizing real-world problems to enhance their science and mathematical knowledge while engaging in the engineering design process. They also saw teachers' beliefs and practices with regards to use of technology in their classrooms and ways to integrate individual disciplines into STEM subjects.

"STEM Teachers' Job Satisfaction: From the Lens of Job Demands-Resources" by Ke Wang and Yu Xiao explores the theory of job-demands-resources or JD-R to explain job satisfaction of STEM teachers. The authors examined the JD-R model developed by Bakker et al. (2005) using factors such as support of society, teacher relationship with his/her supervisor, and burnout due to work demands. They analyzed data from 7905 full-time secondary public school STEM teachers in the U.S. who completed The Schools and Staffing Survey (SASS) administered by the National Center for Education Statistics (NCES) in 2011-2012. Wang and Xiao analyzed three questions from the survey that focused on eliciting activities that teachers spend the most time on during the school year, teachers' main teaching assignment, and the approximate number of hours spent on teaching mathematics and science subjects. Their research findings suggest students' misbehavior and background are factors that influence teacher job demands, while support from colleagues, school administrators, and distributed leadership contribute to job resources for teachers. Moreover, they found that job resources had a significant, positive effect on teacher job satisfaction, while job demands generally had a negative impact on job satisfaction.

Robyn Ruttenberg-Rozen, Katelin Hynes, and Ami Mamolo's chapter "A case study of a female pre-service teacher learning to code for mathematics teaching: Analysing emotions and attitudes through a gender lens" is a response to disruptive gender stereotyping that prevents women from pursuing careers in computer science, advocating supporting women to learn how to code. Her qualitative case study focused on the experiences of a Canadian middle school mathematics pre-service teacher, Charlotte, during her 16-month education program that focused on technology. Using data from Charlotte's spoken-word video reflections of personal reflective accounts, the author noted that this case "highlights the precariousness of attitudes related to self-efficacy, belonging, and identity, and emphasizes the importance of supportive early experiences when learning to code." The authors point out that experiences in learning to code for teaching are all too often fraught with of uncertainty, intimidation, and feelings of being overwhelmed. These experiences are influenced by negative stereotypes, a lack of prior exposure to coding, and the vastness of the perceived learning requirements. However, their findings do indicate that pedagogies encompassing an ethics of care can offer nurturing, supportive, and inclusive professional development experiences that can, "facilitate learning in a subject area that is perceived as stereotypically unwelcoming, individualistic, and discriminatory towards women."

The chapter titled "Investigation of STEM Awareness Levels of Classroom Teacher Candidates in terms of Problem Solving and Gender Variables" describes a study investigating pre-service teachers' STEM awareness with regard to their gender and problem-solving skill level. The findings revealed that there is no statistically significant difference in pre-service teachers' STEM awareness by their problem-solving skills level (i.e., low and high level of problem solving skills). The results also revealed that female pre-service teachers' STEM awareness is generally higher than male students' STEM awareness. Dr. Bal suggests that pre-service teachers should have positive attitudes towards STEM related fields and majors as they will arrange their classroom practices according to their beliefs and views on STEM related disciplines.

Components Related to Students' STEM Learning Experiences

The underlying purpose of developing effective and appropriate STEM learning contexts and teaching pedagogies is to provide students the best possible opportunities to engage with STEM disciplinary concepts and practices. As described in the landmark report Science for all Americans (Rutherford and Ahlgren, 1991), STEM courses should "equip [students]...to participate thoughtfully with fellow citizens" (p. xiii). More recently the Framework for K-12 Science Education (NRC, 2012) posited that learning outcomes from STEM courses should improve the "civic decision making [that] is critical to good decisions about the nation's future" (p. x) and that students need to learn about STEM topics, specifically science and technology, so that they can "engage with the major public policy issues of today" (NRC, 2012, p. 7). Feinstein (2011) claimed that the aim of STEM should be to prepare students who see that "scientific knowledge and knowledge about science are both relevant and accessible--that someone starting on the outside of a problem, without much background, can plunge into the deep water of conflicting expertise and emerge with something resembling an answer" (p. 182). Rodriguez & Berryman (2002) also identified the goal of moving students closer to a sense of consciousness and agency in their own ways of learning. They define agency as "the conscious role that we choose to play in helping to bring about change for the benefit of all and especially for the benefit of those who occupy disadvantaged positions in comparison with ours" (p. 1020). Lee (2005) stated that, "from a critical theory perspective, desired science outcomes include agency and empowerment, as students become aware of social injustice and inequity-the unequal distribution of social resources and the school's role in the reproduction of social hierarchy-and take actions to address such problems in their communities" (p. 493). If STEM schooling and learning is geared toward this goal, it can attend to a longstanding, recognized need for students to see what they learn about in school as a relevant and necessary part of navigating their own life and sustaining their cultures (Ladson-Billings, 2014). The need for effective STEM education to produce a scientifically literate populace, able to tackle issues pertinent to their own lives and well-being is widely accepted, however, there is no similar agreement as to what classroom experiences are best to facilitate this outcome.

This section dives into issues related to STEM learning experiences for students. The first chapter reports findings from a meta-analytic study investigating the relationship between self-efficacy and interest in a STEM career and the various student factors that influence this relationship. The next chapter outlines the value and awareness Brazilian high school students place on mathematics and science as well as their perceived abilities in these subjects. The final chapter looks at how simulation-based formative assessments impact students' conceptual understanding in physics.

The chapter conducted by Dr. Katherine Vela and Sandra Miles outlines the meta-analytic study investigating the relationship between self-efficacy and interest in a STEM career. Vela and Miles define self-efficacy and describe how it is developed and measured. They also describe the connection between self-efficacy and STEM career choices. In their meta-analysis, they located 39 studies to determine what student factors (e.g., race, gender) influence the degree of this relationship. They found that there is a positive relationship between self-efficacy toward STEM and pursuing a STEM career. In addition, their results revealed that the factors (i.e., race, gender, and participating in STEM intervention) did not have statistically significant ($p > .05$) effect on individual STEM related self-efficacy.

The chapter titled "Students' Awareness, Perceived Ability, Value, and Commitment to Science and Mathematics: A Perspective from High School Students in Brazil" by Adriana Leonidas de Oliveira, Augusto Macalalag, Jr., Maria Cecília Barbosa de Toledo, Marcia Eliza de Godoi dos Santos, Zachary Minken, and Charu Varma analyzes the STEM identity from an international perspective. This mixed research method study seeks to answer the following research question: What are Brazilian high school students' awareness, perceived ability, value, and commitment to science and mathematics? While the quantitative data are gathered from analyze 291 high school students to analyze their awareness, perceived ability, value, and commitment toward science and mathematics disciplines inside and outside of school contexts, the qualitative data are collected from semi-structured interviews with 12 high school students to provide detailed information about the research question. The research findings show that students are more aware of science compared to mathematics and find mathematics to be more challenging than science. However, it is important to state that most students value both mathematics and science. The research results also show that there is no gender difference in STEM identity between male and female students. Both qualitative and quantitative data collection instruments are provided as appendixes in the chapter.

The final study titled “Effects of Simulation-Based Physics Assessment on Students’ Conceptual Understanding" was conducted by Dr. Park. In this study, Dr. Park investigated the effects of computer simulations on students’ conceptual understanding of physics and scientific ideas. This study informs that college students sampled in Dr. Park’s study hold misconceptions about force and motion although they completed an introductory physics course. This study suggests that college students’ misconceptions and difficulties with conceptual understanding of physics and understanding scientific ideas can be eliminated through implementing computer simulations. This is because Dr. Park observed that when simulations are used, college students are able to transform their superficial and fragmented knowledge to be more structured and connected. In addition, it was observed that simulations along with formative assessment let students develop their normative explanations of scientific ideas.

Editors and Chapter Contributors

Dr. Augusto Macalalag, Jr., associate professor and director of Science, Technology, Engineering, and Mathematics (STEM) Education program, teaches undergraduate and graduate science methods courses to pre-service and in-service teachers. Before joining Arcadia University in Pennsylvania, U.S.A., he taught mathematics and sciences to middle and high school students in New Jersey. Dr. Macalalag received his Ed.D. in Science from Rutgers University, and an M.A. in Education and a B.S. in Chemistry from St. Peter’s University. In 2014, he conceptualized and developed the M.Ed. in Integrative STEM Education and Graduate Certificate for in-service elementary and middle school teachers. His research and courses have contributed to better understanding on how to cultivate the teachers’ knowledge of science and the engineering design process, teachers’ cultural awareness of socioscientific issues in an international setting, and improve pre-service teachers’ awareness and intentions of teaching STEM subjects to undergraduate students in

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Dr. Ismail Sahin, a professor of Curriculum and Instruction (C & I), is the editor of International Journal of Education in Mathematics, Science and Technology (IJEMST). His research interests are mainly on curriculum and instructional technology. Dr. Sahin received his master degree in education from University of Missouri, Columbia, Missouri, United States in 2002and his PhD degree in Curriculum and Instruction with an instructional technology specialization from Iowa State University, Ames, Iowa, United States in 2006. He taught undergraduate and graduate level research methods courses. He has published many papers from his independent or collaborative research studies. He is involved in the publication of many journals and the organization of many academic conferences. His research and publications have contributed to better understanding of the impact of education technology in developing new methods to strengthen student learning and thereby deepen the expertise of the worforce.

Dr. Joseph Johnson is an associate professor and chair of the Physics Department at Mercyhurst University in Erie, PA. He teaches introductory and upper-level undergraduate physics courses and graduate education courses. He received his PhD at the State University of New York at Buffalo in Science Education. The body of his professional research is situated in the field of science and STEM education, specifically focused on best practices in physics education, STEM teacher preparation, science education for English language learners, particularly focused on refugee groups, equity and diversity in science education, and best practices in educational technology. His current research projects include working on a large NSF funded grant focused on socioscientific issues and STEM teacher professional development and a separate project exploring the kinesiology and biomechanics in the sport of disc golf.

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SECTION I - LEARNING CONTEXTS IN TEACHING OF STEM DISCIPLINES

Chapter 1 - Encouraging STEMpathy: A Review of Literature Addressing STEM Learning for Students with Special Education Services in Inclusive Learning Environments

Joseph Johnson, Michael Zielinski, Jessica N. Essary, Kim Dean, Keri Bartynski, Augusto Z. Macalalag

Chapter Highlights

- Socioscientific Issues (SSI) is a framework that can provide inclusive inquiry opportunities to allow all learners to engage in STEM disciplinary concepts and practices because all students potentially relate to the controversies in their local environment.
- Many students have formal individualized goals relating to Social Emotional Learning (SEL) and SSI methodology parallels strategies that build emotional regulation, empathy and executive functioning skills in students with challenges in those areas.
- Technically identified needs (TIN) for students can be formally identified by experts who evaluate the student with various instruments.
- Student centered STEM education with a Socioscientific focus has the potential to empower students in solving problems and seeking answers that are relevant to their own lives and to their communities.
- By design, the topics in SSI tend to be inclusive because all students have the potential to relate to the controversies in their local environment.

Introduction

"There is continuing tension on the research of exceptional learners in science. A major contributing factor is the tendency for special education and science education researchers to emphasize preferentially different theoretical views on learning and teaching (McGinnis & Khan, 2014, p.241)." Many Science, Technology, Engineering, and Mathematics (STEM) topics may provide a potentially rich learning environment, including experiential learning and sensory learning, for meeting the needs of all student populations and multi-age groups. However, perhaps due to the partisan theoretical camps (McGinnis & Khan, 2014), a scant amount of research investigates the possibility of liberating science for all children through STEM methods.

In this chapter, we review literature which predominantly suggests that Socioscientific Issues (SSI) is a framework that can provide inclusive inquiry opportunities to allow all learners to engage in STEM disciplinary concepts and practices as well as to meet individualized learning goals. In SSI lessons, children have the opportunity to analyze challenges, ranging from local to global, related to STEM topics. For example, in a class integrating SSIs students may debate large scale issues like nuclear power, deforestation, or climate change, or discuss local issues like local bike helmet regulations or beach restoration projects (Zeidler & Khan, 2014). Addressing topics such as these in the SSI framework allows students to approach STEM topics in contexts that they are familiar with outside of the classroom, while also wrestling with important moral and ethical concerns, and thus integrating their STEM learning with other important lessons like empathy, perspective taking, analysis of information, and scientific argumentation. SSI curriculum and approaches, rooted in students' lived experiences, employ hands-on, active learning and empower students to take agency in the challenges they identify as important. Therefore, SSI has potential to support enhanced motivation for engagement of all students.

In this chapter, we explore why students with special education needs are less likely to access STEM education. We also describe the significant value of the SSI model in meeting students with technically identified needs (TIN) where they are, and to interact with students in ways that are particularly well suited to their learning challenges. SSI enables students' development of STEMpathy, a term which evokes emotionally intelligent, person-first, empathic application of STEM problem solving and design. These social-emotional learning opportunities are valuable for all students, but these are often the explicit individualized goals of students with disabilities. Successfully including the frequently marginalized population of students with special needs in STEM is an important goal for educators. However, it is also critical to recognize the challenges which can occur and suggest recommendations for inclusive SSI based on the literature detailed within this chapter.

What are Technically Identifiable Needs?

All children have individual needs that can impact learning in the classroom. However, only some children are formally recognized for diverse learning needs. These needs are formally identified by experts who evaluate the student with various instruments (e.g. observation protocols, etc.). Using these instruments, school based teams determine if the child has any technically identified needs (TIN) which impact their learning or access to the curriculum as per school eligibility requirements in one of 13 categories i.e., which may be labeled as specific learning disabilities affiliated with a medical diagnosis, sensory-impairments, psychological, and/or psychiatric needs as delineated within the DSM-5 (APA, 2013). The data related to the TIN are used to determine programming and design service support in the classroom. If services are provided in the general education classroom, the child is receiving an inclusive education. If a lead teacher does not have a certification to support an inclusive classroom, sometimes this involves having a special educator co-teach with the lead teacher. If the child is removed from their peers in general education, this is not an inclusive education, and these challenges will be addressed within the chapter.

According to the National Center for Education Statistics approximately 14% of children ages 3-21 received special education services (i.e. only allotted to children with TIN/s) during the 2018-2019 school year in the United States (NCES, 2020). There are a variety of diverse learning needs among children and not all children have TINs. Some learners who might warrant services fail to be formally identified, others are misdiagnosed, some have multiple needs, some children have temporary needs, others have situational needs, and many learners maintain a variety of diverse learning needs which may not warrant formal identification. Considering the diverse experiences in life, and the diversity of humanity, we can all assume that every child has some form of special learning preferences and needs for learning with only some having TINs. In summary, all humans are differently-abled. There are a variety of needs among learners, and not all needs require a technical diagnosis.

Challenges in Achieving Inclusive Education

In addition to recognizing that science has been somewhat removed from inclusive education dialog (McGinnis & Khan, 2014), even educators with various expertise associated with certain TINs rarely agree on the value of inclusion.

> *Inclusive education is a contested domain with positions ranging from strident opposition through cautious support to strong advocacy. Some stakeholders have taken a middle-of-the-road position because while they endorse the human rights discourse that makes inclusion a global imperative, they are caught up in a dilemma between their aspirations and the realities at school level which leave them uncertain of exactly what gains and losses might be involved in a total commitment to inclusive education (Materechera, 2020, p.771).*

Yet, if program dynamics and classroom contexts were more inclusive than many of these philosophical debates on whether inclusion matters may become moot academic arguments. Research interviews conducted to study teacher's perspectives on inclusion in South Africa, Thailand, and Ireland respectively, suggest that major vicisitudes occur when inclusive education efforts are not well supported with the following; 1) planning time, 2) funding, 3) inclusive instructional time, 4) small teacher/student ratios, and 5) familiarization sessions to educate all teachers on diverse inclusive needs yet maintaining lines of accountability for each stakeholder involved in supporting a child (e.g. profound TINs which also involve vital medical care considerations, TINs which may cause concern for the physical safety of others in the environment, etc.) (Materechera, 2020; Klibthog & Agbenyega, 2020; Ní Bhroin, & King, 2020). These contextual limitations tend to cause teachers great stress and impact their interest in maintaining collaborative engagement and inclusive environments (Ní Bhroin, & King, 2020). For the purpose of this article, we will refer to learners with specific TIN/s, or diverse learning needs among all children, in an effort to be inclusive. This effort avoids the common label 'exceptional learners' in order to maintain person-first language in our nomenclature.

While one-third of of the students formally identified for special education services are served under the category of "Specific Learning Disability" (SLD) in America, "disruptive behavioural problems such as temper tantrums, attention deficit hyperactivity disorder, oppositional, defiant or conduct disorders are the most common behavioral problems in preschool and school age children" (Ogundele, 2018, p.9). In addition, some children may be currently unidentified but require additional support to reach optimal learning potentials. Interactive and inclusive science teaching practices are warranted for all children, because research suggests children with technically diagnosed needs tend to benefit from nontraditional education methods which involve interactive, inclusive practices (Sternberg & Grigorenko, 2002; DeBruin, 2020).

Inclusive Education

Analytical scientific skills may be enhanced through authentic lessons which relate to a child's immediate life context (Johnson, 2011) and avoid overemphasis on memorization (McGinnis & Khan, 2014, p. 241). Despite the potential of STEM contexts for engaging students in special education, inclusive education with STEM learning has been largely overlooked in the body of related research. Furthermore, there is a dearth of literature which suggests methods for supporting inclusive STEM learning for children with TINs associated with emotional disturbances. Diverse learning needs require pluralistic behavior guidance in the classroom and partnerships with a variety of professionals. SSI involves authentic, real world, science-based societal issues that, when studied, require students to develop scientific content knowledge as well as moral and ethical reasoning skills (Dolan, Nichols, & Zeidler, 2009). Inherent to the SSI method is consideration of children's socio-emotional learning (SEL), informed by literature which relays the positive impact of SEL curriculum on children's cognition (Mahoney, Durlak & Weissberg, 2018) as well as the proactive teaching of the set of collaborative skills students need to navigate student centered, inquiry based STEM where youth work together and engage in discourse around controversial issues. One framework describing SEL defined five inherent competencies, self awareness, self management, social awareness, relationship skills and responsible decision making (Immordino-Yang, Darling-Hammond, & Krone, 2018). Substantial overlap exists between these competencies and SSI practices. In engaging students in STEM content through application of SSI, teachers also enhance social awareness. Social awareness is heightened while creating relationships between the student and their community. This is accomplished when students look at outcomes, data, and source information and make decisions accordingly.

Inclusion was defined by the National Center on Educational Restructuring and Inclusion (NCERI) as "providing to all students, including those with severe disabilities, equitable opportunities to receive effective educational services, with supplementary aids and support services as needed, in age-appropriate general education classes in their neighborhood schools, toward the outcome of preparing all students for productive lives as full members of the society" (1995). Notably the term "inclusion" was first used in the global context in the Salamanca Statement in 1994 calling for the development of inclusive schools and access for children with disabilities (Rodriguez & Gil, 2014). As early as 1999 Lipsky and Gartner argued that inclusion was not just another approach to improved delivery of special education services but rather a strategic investment toward equitable access to opportunity and quality education critical to a democratic society. Inclusion is achieved when children with TINs are *included* in classroom activities with peers who do not have documented TINs. Equity does not equate (i.e. fairness) to equality (i.e. having equal access). In order to create fair learning environments, some children will require modifications or accommodations to increase accessibility, flexibility, mobility, visibility, or other aspects of the learning environment. Sometimes these aspects benefit all learners (e.g. using flexible seating), but other times the child will need something different than peers for the environment to be fair (e.g. assistive technology for profound TINs). Unfortunately, children with or without documented TINs tend to shy away from STEM subjects. Furthermore, in general, U.S. students often have a tendency to avoid STEM areas (Apedoe, Reynolds, Ellefson, & Schunn, 2008; Lam, Doverspike, Zhao, Zhe, & Menzemer, 2008). Yet, SSI provides a strong framework for engaging students and teachers in meaningful and relevant scientific discourse in the development of functional scientific literacy (Macalalag, Johnson, & Lai, 2019). This framework, "focuses specifically on empowering students to consider how science-based issues and the decisions made concerning them reflect, in part, the moral principles and qualities of virtue that encompass their own lives, as well as the physical and social world around them" (Zeidler, Sadler, Simmons, & Howes, 2005, p. 360). Curriculum of this kind has the potential to impact how and why students engage in STEM content. "Interventions to make the environment more facilitating enable people to do the things that matter to them and that improve wellbeing" (Cieza, Sabariego, Bickenbach, & Chatterji, 2018, p.1).

By design, the topics in SSI tend to be inclusive because all students have the potential to relate to the controversies in their local environment. Moreover, all students can contribute relevant perspectives to consider within their shared local context which defines each issue. Through engaging in SSI, children may discover or rediscover a fascinating world full of diverse socio-scientific challenges and creative scientific solutions. With a shared relevance to the issues and the need for diverse ideas in order to solve the problems, involvement is liberated to individuals despite their abilities. Empathetic SEL interactions help to move the collaborative student SSI teams forward with case-study discoveries.

Current Reforms and Trends in Special Education Services

Globally we still have a long way to go to achieve universal access to education since currently, 1 in 5 children will never enter a school and 15% of those children are excluded from school due to disability (UNESCO, 2016). In 2006, the United Nations General Assembly adopted the *Convention on the Rights of Persons with Disabilities* reflecting a shift in how the world views individuals with disabilities as persons with rights. The United Nations Sustainable Development Goals (SDGs) 2030 were adopted in 2015 and aspire to more fully address the education access rights for children with disabilities. Goal 4 addresses ensuring *inclusive* and *equitable quality* education and promoting lifelong learning opportunities for all. Currently, 193 countries have formally adopted these goals which speaks to the emerging good practices in equitable access to inclusive education taking shape across the world.

Internationally a significant number of school age students present with diverse learning needs in the classroom. In the United States 14 percent of all public school students ages 3–21 received special education services under the Individuals with Disabilities Education Act (IDEA) in the 2019–20 school year. These students do not include the students who struggle with typical academic demands who have not been formally identified as eligible for an Individualized Education Plan (IEP) that would hold schools accountable for adaptations, accommodations, and specially designed instruction in support of their success. The prevalence of developmental disability among US children aged 3 to 17 was approximately 18% in 2017. Many disability advocates endorse the “1 in 5” estimate of learners in the classroom who may struggle to succeed (DuPaul, Gormley & Laracy, 2013) suggesting that developing curricula designed with flexibility and accessibility in mind is a strategic good for all students.

The Individuals with Disabilities Education Act (IDEA) is a U.S. federal statute designed to ensure the free appropriate public education (FAPE) in the least restrictive environment (LRE) for children with disabilities. These disability categories include ‘‘autism, deafblindness, emotional disturbance, hearing impairment, intellectual disability, multiple disabilities, orthopedic impairment, other health impairment, specific learning disability, speech or language impairment, traumatic brain injury, and visual impairment'' (IDEA, 20 U.S.C. § 1400, 2004). Once a student qualifies under one of the thirteen exceptionalities for special education services, IDEA requires that all students receive those services in the least restrictive environment (LRE) (Wrightslaw, 2018). Educational agencies must comply with the IDEA regulations including FAPE and LRE in order to be qualified for federal funds. Each public agency must ensure that:

> (i) To the maximum extent appropriate, children with disabilities, including children in public or private institutions or other care facilities, are educated with children who are nondisabled; and
>
> (ii) Special classes, separate schooling, or other removal of children with disabilities from the regular educational environment occurs only if the nature or severity of the disability is such that education in regular classes with the use of supplementary aids and services cannot be achieved satisfactorily (20 U.S.C. 1412(a)(5)).

Since PL94-142 reauthorization in 2004, the Individuals with Disabilities Education Act (IDEA) special education advocates have moved toward the hope of maximally inclusive programming and access to the general education curriculum as equivalent to the goal of ensuring that every child's individual needs are effectively addressed. Globally there has been support for the evolution of inclusive models of special education and educational development goals have emerged moving away from approaches which exclude students from access to the general education classroom and curriculum.

In much of the U.S., inclusion is the expected norm for students in public schools. Further, many special education reformers have sought to make early intervention, Multi Tiered Systems of Support (MTSS) and high quality Universal Design for Learning (UDL) part of common practice as strategies for reducing the need for students to be served outside of their general education classroom in their neighborhood school with typically developing peers. Classrooms continue to become increasingly diverse with regard to culture, language, disability status, and race. Reducing the impact of barriers to learning is at the heart of the movement toward creating learning environments and curricula designed to flexibly meet the needs of diverse student populations with frameworks like UDL (Courey, Tappe, Siker, & LePage, 2013).

In the United States a majority of special education students—64.8 percent spend 80 percent or more of their time in regular education classes, according to 2019 data. That number has more than doubled in recent decades. In 1989, only 31.7 percent of students spent 80 percent or more of their time in regular classes. Inclusive special education services are delivered in a variety of models. Some school districts have adopted the model of service identified as inclusive learning support. This model of service allows students with TINs to have their needs met in the general education classroom. Depending upon the school district, inclusion may allow for co-teaching opportunities. Co-teaching is an increasingly used inclusive practice implemented by administrators to provide effective instruction in classrooms that have students with diverse learning needs (Goldhaber, Krieg, Theobald, & Brown, 2014). Ideally, co-teaching employs collaboration among two qualified teachers; one special education teacher and one general education teacher. The general education teacher may be highly qualified in a specific subject area. Successful co-teaching classrooms include interaction among all students, shared responsibilities from each teacher, utilization of all classroom spaces, collaborative work ethic, and ideally, an inability to distinguish the general education teacher from the special education teacher (Conderman, Bresnahan, Teacher, & Pedersen, 2008).

Co-teaching has several different models; of these, "station teaching" can provide a meaningful way for general educators and special educators to work collaboratively in a science, technology, engineering, and mathematics (STEM) inclusive classroom (Moorehead & Grillo, 2013). Mofield (2020) indicated that co-teaching adds value to every student's educational experience due to the collaboration involved by teachers and students in this model. Benefits include academic gains, peer acceptance, less behavior incidents, and improved attendance. Another common model of inclusive special education involves special education teachers serving as consultants in support of the general education teacher's application of adaptations and accommodations in the general education classroom. This may also include the special educator "pushing in" to the general education classroom as a physical presence supporting identified students. Most students with TIN spend some part of the school day in resource classrooms where they receive specialized instruction responsive to their individual needs.

The plan developed for students identified for special education services is called an Individualized Education Plan (IEP) and the goals delineated in that plan drive the type of placement and specific instructional strategies, adaptations, and accommodations provided. A common approach to identifying daily schedules for delivery of individualized and/or remedial instruction to students with IEPs outside of the student's general education classroom (resource room model) is to do that during core academic activities in reading and math. Especially in K-8 classrooms, inclusion is frequently targeted to "Special" subjects like Music, Physical Education, Art, as well as Science and Social Studies. Alternatively, scheduling of specially designed instruction or related services (speech, physical/occupational therapy, counseling services) can sometimes supersede less favored specials and/or science or social studies (Scruggs, Mastropieri, & Okolo, 2017). Many special education students have had inconsistent exposure to science education and are at risk of gaps in foundational knowledge and skills as well as a history of academic failure resulting in downward spiraling motivation and engagement in science (McGeown, Norgate, & Warhurst, 2012).

STEM Education in Special Education Settings

Despite the roadblocks impeding STEM education in special education, potential exists for STEM to provide a powerful venue for meeting student needs. Educators, in engaging students in authentic, cross-curricular STEM lessons, facilitate the development of science literacy, scientific discourse, and analytical thinking (Johnson, 2011). Through his SocioTransformative Constructivism framework, Rodriguez (1998) described how the elements of dialogic conversation, authentic activity, metacognition, and reflexivity allow students to participate actively in discourse that has important implications in their lives outside of the classroom. It is through participation in these dialogic conversations and application of scientific discourse students begins to construct knowledge, develop functional scientific literacy, and address issues of agency and power. As Lemke (1998) wrote,

> [T]he progress of learning in these classrooms was manifestly a function of these small details, that it was the dynamic development of a trajectory of meaningful action, socially shared and jointly constructed by teacher and students, that produced learning. I think that every teacher knows this; we all seek to make meaning jointly with our students, to become engaged together in scientific sense-making, scientific doing. (p. 3)

This suggests that knowledge is socially constructed and mediated by sociocultural, historical, and institutional contexts. Social interactions in which ideas are explored provide opportunities for students to construct knowledge as each participant is able to reflect on and make sense of what is being communicated. Vygotsky (1978) pointed out the importance of language in this process, indicating that children's development of thought occurs concurrently with the acquisition of language. The words, images, and gestures used in social exchanges provide the tools necessary for individual thinking and meaning making. These tools are internalized through social interactions (Scott, Asoko, & Leach, 2007). According to this theoretical perspective, it is the responsibility of the teacher to make scientific knowledge available on the social plane of the classroom, supporting students as they try to make sense of it (Scott, Asoko, & Leach, 2007). In this way, teachers can facilitate the development of functional scientific literacy, a construct of literacy that seeks to bring into the classroom the discourse that the public actually engages in with science (Ryder, 2001).

As will be described in subsequent sections, the SocioScientific Issues (SSI) framework provides a strong foundation for engaging students and teachers in meaningful and relevant scientific discourse in the development of functional scientific literacy (Macalalag, Johnson, & Lai, 2019). Within the SSI framework, functional scientific literacy, unlike more traditional conceptions of science literacy, is "dynamically mediated by personal cognitive and moral developmental considerations. These considerations include factoring in character and cognitive and moral development and include the use of (but may not be limited to) cultural, discourse, case-based, and nature of science issues" (Zeidler & Nichols, 2009, p. 49). This type of socialization and social knowledge construction is valuable for all developing students, and particularly vital for students in emotional and behavioral special needs classrooms. Many students with emotional and behavioral difficulties need social skills training to help them develop more competent and prosocial behavior (Bierman, 2004), yet such efforts may not be effective or sustained if the natural social dynamic processes are operating in ways that compete with the desired social and behavioral outcomes (Farmer et al., 2018). SSI methods encourage collaborative, inquiry, discourse, argumentation, and decision making skills as students are required to recognize and acknowledge multiple perspectives and resolve conflicts (Zeidler & Nichols, 2009). Implicit in these SSI pedagogies are the SEL competencies previously listed, self awareness, self management, social awareness, relationship skills and responsible decision making (Immordino-Yang, Darling-Hammond, & Krone, 2018). Thus, there is significant potential benefit in supporting social interventions like SSI that include strategies involving the management of classroom and social dynamics in ways that help children to develop roles and relationships that evoke and reinforce prosocial skills (Farmer et al., 2018). STEM subjects in general, and SSI strategies in particular, can provide a venue for such an intervention.

Unfortunately, students tend to shy away from STEM subjects. While not all sub-disciplines within STEM share the lack of enrollment, persistent issues exist in subjects like physics, engineering, and mathematics, particularly in terms of underrepresentation of women and ethnic minorities (van Aalderen-Smeets & van der Molen, 2018). U.S. students tend to avoid majoring in STEM areas as the percentage of students interested in the sciences has continuously decreased (Apedoe, Reynolds, Ellefson, & Schunn, 2008; Lam, Doverspike, Zhao, Zhe, & Menzemer, 2008) and nearly half of high school graduates do not reach benchmarks in STEM subjects indicating college readiness. Students often experience major difficulties in mathematics and science from elementary school through college, which propagates and reinforces negative views of STEM (Hwang & Taylor, 2016).

These discrepancies are even more apparent for students with TIN when compared to their peers. While comparing international scores of students with TIN is extremely difficult due to varying definitions for determining disability, nationally, students with TIN perform significantly lower than their peers (Aronin & Floyd, 2013; Basham & Marino, 2013). Traditional methods in STEM classrooms are ineffective in sustaining desired academic, social, or behavioral outcomes. Common barriers to accessing STEM education for students with TIN include a lack of STEM role models (Lee, 2011), misperceptions among teachers and parents that students with disabilities cannot be successful in STEM, lack of appropriate encouragement, information, and counseling (Alston, Bell, & Hampton, 2002), accessibility issues in labs, and a teacher lack of knowledge regarding how to include students with disabilities (Dunn et al., 2012). These are major challenges to implementing an effective STEM curriculum for this population. Without the requisite tools for participation, students may become disillusioned, believing that they are incapable of succeeding, or even participating, in STEM, which can lead to additional behavioral issues and withdrawal (Martin, Papworth, Ginns, Malmberg, Collie, & Calvo, 2015). Students in turn develop negative attitudes toward STEM subjects as they progress in school and encounter increasing complexity and instructional materials that reduce their ability to access and comprehend science content (Lee & Erdogan, 2007).

Yet, if curriculum is structured such that students learn that they can participate and contribute to class, they will in turn develop the appropriate discourse for this participation. These communication tools are internalized through social interactions (Scott, Asoko, & Leach, 2007), however, if this unpacking of science discourse is not actively pursued and promoted among students in traditional classrooms, it never develop on its own (Michaels & O' Connor, 1990) and, consequently, students are left outside of powerful forms of discourse that would otherwise change their life and career trajectories. Despite its challenges, researchers argue that a student-centered classroom, which accounts for and validates the individual culture and background that each student brings to the classroom, can result in increased engagement and authentic learning that is not easily measured on the limited standardized tests (Rodriguez & Kitchen, 2005). Such nontraditional teaching methods have proven effective for students with technically diagnosed needs as well (Sternberg & Grigorenko, 2002). Yet, many teachers lack the knowledge and skills to make accommodations or modify instruction and materials to meaningfully engage students with disabilities in STEM courses (Dunn et al., 2012).

Duschl and his colleagues (2007) proposed four strands of scientific learning to be woven throughout lessons, so that students:

1. know, use, and interpret scientific explanations of the natural world;
2. generate and evaluate scientific evidence and explanations;
3. understand the nature and development of scientific knowledge; and
4. participate productively in scientific practices and discourse.

According to the authors, the four strands are of equal importance and by experiencing all four strands, students are more likely to grasp important ideas in science (Duschl et al., 2007). Unfortunately, the didactic methods that have come to dominate the classroom clearly focus only on the first (Yerrick, 1999). Fortunately, directed coursework and professional development has proven effective in impacting teacher pedagogy in STEM classrooms to enhance learning (Macalalag, Johnson, & Lai, 2019). Cawley, Hayden, Cade, and Baker-Kroczynski (2002) provided teachers with extensive preparation focusing on effective science instruction. With these teacher supports in place, they found that students with disabilities passed district science exams at the same rate as peers without disabilities. Marino (2010) described how effective implementation of technology can further support student understanding of STEM-related learning.

Despite the potential of STEM contexts for engaging students in special education settings, this has been largely overlooked in the body of research. According to Brigham, Scruggs, and Mastropieri (2011) the *Handbook of Research on Science Education* does not even include the term learning disability within the index of over 1,300 pages regarding science education. They further explain that very little intervention research exists in science with students with learning disabilities. Exploring the characteristics of the learners inside and outside of the classroom in comparison to the demands of science curriculum can and should provide guidance in supporting science learning (Yerrick & Johnson, 2009) and in creating interventions in support of students with TIN (Brigham, Scruggs, & Mastropieri, 2011). The surprising lack of content regarding the needs of individuals with TIN in the general education literature indicates the need for support for teachers in meeting the needs of their students with identified learning needs. Novice teachers often enter the field having learned through observation how to teach based on their own school experience (Lortie, 1975). While this experience may have worked for them, the strategies they feel comfortable with may not be appropriate for students who do not share these teachers' backgrounds (cultural, socioeconomic, etc). Too often, inexperienced teachers are unwilling or unable to adapt their pedagogy, even in the face of student failures due to their teaching methods (Yerrick, Ambrose, & Schiller, 2008). Many, if not most, adults were taught science as a system of facts and theories by reading textbooks and memorizing the conclusions that scientists had previously reached. Success in science was likely regarded as possessing a certain body of declarative knowledge about things that had happened in the past and being able to identify these in assessments (Bransford & Donovan, 2005). However, the nature of science and what it means to know and do science has shifted. Lemke (1998) argued that science education ought to empower students to use science discourse tools in meaningful and appropriate ways, and, most importantly, to be able to integrate them as they engage in scientific activity. The current understanding of the nature of science suggests that competence requires students to develop: 1. familiarity with a discipline's concepts, theories, and models; 2. an understanding of how knowledge is generated and justified; and 3. an ability to use these understandings to engage in new inquiry (Bransford & Donovan, 2005, p. 398). Shifting the science curriculum towards a more active and inquiry-based foundation necessitates shifting away from the fact and memorization centered "traditional" means of teaching science. The "traditional" pedagogical approach to science involving the presentation and regurgitation of facts, the memorization and theories and laws, and generally passive participation by the students does not allow for culturally responsive teaching or for addressing the various learning needs of the students. SSIs can, however, be a powerful tool for reaching both of these ends.

SocioScientific Issues

Teaching through inquiry has a long history in STEM education. From the early 1960s until today, researchers and teacher educators developed curriculum materials and professional development programs to encourage teachers to implement how to do science and how to think like a scientist in their classrooms (Duschl et al., 2007). The inquiry process includes engaging students to ask questions, give priority to evidence, formulate explanations, connect explanations to scientific knowledge, and communicate and justify explanations (NRC, 2012). Unfortunately, research studies showed that teachers struggled to conceptualize and teach through science inquiry such as implementing "cookbook" procedures or simple investigations that involve comparing and contrasting of variables (Chinn & Malhotra, 2002) as well as having "folk theories of inquiry" in which a hypothesis functions as a guess about an outcome, but not necessarily part of a larger explanatory system (Windschitl, 2004). The Next Generation Science Standards (NGSS Lead States, 2013) was designed to help guide K-12 science education using three dimensions: disciplinary core ideas, science and engineering practices, and cross cutting concepts. The disciplinary core ideas describe learning progressions of fundamental scientific ideas in grades K - 12 in four domains: physical science, life science, Earth and space science, and engineering, technology, and applications of science. While the cross cutting concepts are "concepts that bridge disciplinary core boundaries, having explanatory value throughout much of science and engineering. These concepts help provide students with an organizational framework for connecting knowledge from the various disciplines into a coherent and scientifically based view of the world" (NGSS Lead States, 2013, page 83). The final dimension of NGSS is science and engineering practices, which unlike the version of inquiry process that is only focused on scientific investigations to inquire about our natural world (NRC, 2006), this new version intertwines with the engineering practices to improve our designed world.

The science and engineering practices include (a) asking questions and defining problems, (b) developing and using models, (c) planning and conducting investigations, (d) engaging in argument from evidence, (e) using mathematics and computational thinking, and (f) constructing explanations and designing solutions (NGSS Lead States, 2012). The study conducted by Macalalag and Parker (2016) showed successes and challenges of enhancing teachers' knowledge of science and the engineering design process with respect to models and modeling as well as energy transformations. Teachers also improved their notions with regards to defining the problem, collecting and interpreting data, and revising and presenting final models. However, they struggled to connect the object in question (a coat for us on Mount Everest) to their science and engineering practices. Moreover, most did not include identifying constraints and planning investigations as part of their steps.

In addition to incorporating the three dimensions of NGSS (2013), Zeidler (2016) argued that these are insufficient to develop students' functional scientific literacy in order to evaluate information, examine multiple perspectives, consider moral and ethical dilemmas, and recognize cultural backgrounds before making sound decisions. Other researchers have argued that if scientific literacy is indeed a central and important goal of science education, "then scientific literacy must entail, at least in part, the ability to thoughtfully negotiate SSI and contribute to discourse regarding these topics" (Sadler et al., 2006, p. 354). The social and subjective nature of moral, ethical, socioscientific issues, provides an avenue to engage students in discourse that addresses the many aspects of the nature of science (Zeidler, Walker, Ackett, & Simmons, 2002). Discourse includes, "a large set of issues rather than simply ways of speaking. Discourse is a socially accepted association among ways of using language, of thinking, and of acting that can be used to identify oneself as a member of a socially meaningful group" (Gee, 1987, p.1). Discourse includes roles and rules of inclusion, allowing identification of individuals as members of the group.

SSI involves authentic, real world, science-based societal issues that, when studied, require students to develop scientific content knowledge as well as moral and ethical reasoning skills (Dolan, Nichols, Zeidler, 2009). By definition, SSIs can include a wide variety of topics such as access to food and impact to human health in urban communities, vehicle speed limits and fatalities in cities, etc. Furthermore, SSI includes the use of "personally relevant, controversial, and ill-structured problems that require scientific, evidence-based reasoning to inform decisions about such topics" (Zeidler, 2014, p. 699). SSI provides a strong framework for engaging students and teachers in meaningful and relevant scientific discourse in the development of functional scientific literacy (Macalalag, Johnson, & Lai, 2019). This framework, "focuses specifically on empowering students to consider how science-based issues and the decisions made concerning them reflect, in part, the moral principles and qualities of virtue that encompass their own lives, as well as the physical and social world around them" (Zeidler, Sadler, Simmons, & Howes, 2005, p. 360). By design, the topics are inclusive because all students may relate to the controversies.

Teachers' PCK for SSI curriculum was demonstrated through the selection of controversial case-based issues (Macalalag, Johnson & Lai, 2019). Teachers cited raising environmental awareness and social responsibility as their objective in using the SSI cases which they selected. Additionally, teachers' PCK includes an awareness of students' background knowledge and how students generally understand specific science concepts, the common misconceptions and preconceptions they may hold, and strategies to help students' learning move forward (Magnusson *et al.*, 1999). Learning about students' backgrounds is especially important in regards to teachers' selection of SSI cases, so that teachers can align SSI cases to students' lives and make them personally relevant (Saunders & Rennie, 2013; Yerrick & Johnson, 2011). Bayram-Jacobs et al. (2019) found that teachers with strong PCK tend to have a strong connection between knowledge of students' understanding and knowledge of instructional strategies. Also, teachers acquire new instructional strategies to promote student ability to critically examine science issues, including classroom activities that engage students in argumentation and discourse (Marco-Bujosa et al., 2017), modeling (Stammen, et al. 2018), and reasoning (Louca & Zacharia 2012; Zhang et al., 2015). The moral and ethical reasoning involved in SSI teaching is what sets it apart from other orientations to teaching science (Zeidler, 2016). Research indicates teachers tend to have difficulty shifting their understanding of STEM away from facts (Ekborg et al. 2013; Leden et al., 2017), which is necessary to effective SSI and social justice pedagogy.

Findings from a professional development (PD) of teachers indicate that the PD activities increased teachers' intention to incorporate SSI in future lessons and pedagogical sophistication (Minken et al., 2021). Moreover, prior to the conference, most participating teachers were unfamiliar with SSI. An analysis of lessons developed after participation in the conference indicated teachers incorporated elements of sustainability and social justice with STEM content and incorporated four or more SSI elements into their lessons. A follow up study with a subset of participants from the conference indicates the benefits of a sustained (5 months), collaborative professional development model grounded in instructional design, implementation, reflection, and revision in the context of daily practice with coaches promoted evolving sophistication with regard to implementing the various elements of SSI, including an increased emphasis on the social aspects of SSI. Yet, participating teachers continued to struggle with balancing the social and scientific elements and developing the critical and discursive nature of SSI in their lesson plans, indicating additional support was needed (Minken et al., 2020). SSI issues can support current initiatives of incorporating Social Emotional Learning (SEL) into inclusive settings. Students competent in SEL have been defined as having the ability to self manage, recognize and regulate emotions, make stable personal relationships, set goals, meet personal and social needs, and make ethical and responsible decisions (Elias et. al., 1997; Payton et al. 2000). SSI practices overlap in pushing students to grow social awareness and empathy while creating relationships between the student and their community, all while looking at outcomes to make decisions accordingly. SEL practices support highly engaging learning environments that enhance students' development of sustained flexible attention, executive control, and emotional relevance (Immordino-Yang, Darling-Hammond, & Krone, 2018). SEL aligns itself with brain development theories to support exploration and discovery followed by reflection and discussion (Srinivasan, 2019). SSI methodology parallels strategies to build emotional regulation and executive functioning skills in students with deficits in those areas. The scientific process of data collection and synthesis, defining a problem, planning, self monitoring, adjusting as necessary, and using strategies to organize thoughts and consider perspectives is a similar process of learning to think adaptively rather than reactively (Marlow & Inman, 2002). In this way, SSI has the potential to provide reinforcement to strategies that are used to address executive functioning and emotional regulation deficits in students identified with Emotional and Behavioral Disorder (EBD). Future research may further address how inclusively designed SSI lessons may contribute to developing student perspectives which support respect for human diversity and inclusion as well.

Practical Implications

The social, active and authentic aspects of SSI have the potential to boost engagement and motivation for all students. However, individual student gaps and academic weaknesses are still relevant to the success of students with TINs. Educators seeking to employ SSI approaches can optimize the engagement and learning of students by attending to the valuable information about the individualized strengths and needs of students in their classrooms. While integrated STEM offers tremendous opportunity for the development of

SEL, improved perspective taking skills, and enhanced/improved academic skills teachers must employ lesson design to minimize barriers and optimize the number of “handlebars“ for students to grasp onto as they pursue SSI.

Supporting students with individualized education plans, as well as students who struggle with social emotional functioning, requires that content area teachers tune into the existing schoolwide or MTSS “tier 2” level social emotional curriculum and interventions in place. As noted earlier students will benefit from alignment in any school-wide vocabulary and curriculum in place to address working collaboratively in groups and engaging in problem-solving, self-regulation, and other interpersonal competencies which make cooperative student groups effective for all students. SSI teachers should attend to the routines that support students' engagement in group work and support the transition between activities which can be a challenge for students.

Additionally, content area teachers will be well served to design units and lessons inside a universal design framework that will minimize barriers based on the likelihood that certain students with TINs will be likely to have gaps in their science and math knowledge due to the complexities of special education programming and delivery. Curriculum and lesson design attending to resources addressing possible gaps is an effective universal approach for language learners, students with TINs as well as other marginalized populations who may demonstrate gaps in their learning for a wide variety of reasons.

Best practices for inclusive SSI would include collaboration with the educational specialists who are most familiar with any given student's needs and strengths. Effective consultation and co-teaching models offer opportunities to expand content area educators’ skills in identifying opportunities to address Specific IEP goals in the context of the science classroom. Special educators seeking to optimize the success of included students frequently approach individual student support as a consultation training opportunity to also support the expanded capacity of STEM educators to effectively manage the complex SEL and academic demands of the inquiry based and student centered SSI classroom. Engaging in proactive problem solving in support of one child’s complex learning needs will arm that teacher with new knowledge and skills as they address the next complex learner who enters the STEM classroom. Thus, collaborative relationships with special educators have the potential to significantly expand the capacity of the general education teacher's tool belt as well as their confidence in supporting diverse students in SSI.

Finally, students who are identified as having particular learning challenges most often have experienced educational struggles and can become disempowered feeling that they have a little agency in their education or in the wider community. Integrated STEM education with a Socioscientific focus has the potential to empower students in solving problems and seeking answers that are relevant to their own lives and to their communities. Providing students opportunities to share their learnings with the wider community can combat the history of disempowerment which many students with TINs experience in formal education while also increasing their motivation to engage in STEM related opportunities.

Recommendations for Future Research

Recognizing the potential of SSI for engaging students with TIN, research is needed in best practices for integrating SSI for students in inclusive settings for the benefit of all learners. Significant bodies of research exist investigating and supporting SSI and inclusive education separately, yet the intersection of these fields remains largely unexplored. Interventional research, particularly in grades following elementary school, is notably lacking regarding students with TIN in STEM (Mastropieri et al., 2009). Further, work is needed in developing effective curricular materials for STEM across a variety of special education settings and service delivery models.

A first necessary step is to raise awareness of the ways that STEM impacts people, particularly students with TIN. In applying aspects of SSI, pre-service teachers begin to expand their view of their role as a science teacher as they address the ways science is relevant in students' lives (Varelas et al., 2018). This type of engagement is particularly important for students with TIN who are often disenfranchised with or shy away from STEM subjects (Hwang & Taylor, 2016). Inherent to the SSI method is the proactive teaching of collaborative skills and discourse tools that students need to navigate student-centered, inquiry-based STEM focusing on controversial issues. This overlaps significantly with SEL competencies (Immordino-Yang, Darling-Hammond, & Krone, 2018), however, given the conspicuous lack of interventional research on STEM for students with TIN (Mastropieri et al., 2009), the need for additional studies exploring this overlap is evident.

To encourage and maintain integration of SSI among pre-service and in-service teachers, teacher education and professional development programs must provide a variety of experiences that allow developing teachers to participate directly in SSI from the students' point of view. In doing so, teachers will develop an extensive repertoire of SSI strategies and contexts, while also learning how to learn, develop, and implement their own SSI lessons focusing on contexts specific to their classroom (Johnson, Macalalag and Dunphy, 2020). This is important for teachers in both STEM certification and special education programs. These types of experiences, engaging in multiple SSI cases, will better prepare teachers to provide culturally relevant and engaging opportunities for their students to build understanding while providing a template for the application of new SSI to teachers' future instruction. This allows them to better align selected cases to students' specific needs, interests and backgrounds at a variety of levels (Johnson, Batkie, Macalalag, A., Dunphy, J., & Titus, S., In Press). Additional research is needed on best practices in both teacher education and professional development to facilitate this process.

Exploration of intersections in student skills required for SSI (collaboration, discourse, problem-solving) and the skills addressed in several frequently used SEL curricula would add to the knowledge base for those hoping to optimize student development in the SSI/STEM classroom. SEL curricula comprise specific skills and that students need to set goals, manage behaviors, build relationships, and process and recall information (Srinivasan, 2019). As noted above, research considering the potential of inclusively designed SSI to enhance students' capacity for perspective taking and respect for human diversity should be undertaken. Research is needed regarding best practices in preparing teachers to address these challenges in both STEM and special education, to incorporate SSI for students with TIN.

Frequently STEM educators and Special Educators practice in homogeneous professional circles. This is true in K-12 settings as well as in the development of research agendas in their respective disciplines. Inclusion in practice requires integration of goals and strategic engagement of the professional expertise in each discipline. Optimal inclusive practice requires purposeful, cross discipline collaboration in the design of curriculum, the logistical planning of special education service delivery, and the execution of STEM lessons so that the potential of SSI STEM to liberate science learning and engagement for all students can be realized.

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Chapter 2 - How and Why Teachers Implement STEM? A Journey to Teacher Beliefs and Teaching Practices

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Chapter Highlights

- Teachers with enthusiasm regarding STEM education adapted student-centered pedagogies, and their teaching practices seem to align with their pedagogies.
- The positive influences of STEM education on students' learning and skills increase teachers' enthusiasm to teach STEM.
- Teachers lack collaboration among colleagues.
- The pressure of standard-based testing seems to hinder teachers' STEM implementations.
- Teachers valued the connectedness of STEM activities to the real world and thought that these connections help students make sense of STEM activities.

Introduction

Today's complex problems that require connecting the knowledge of science, technology, engineering, and mathematics to real-world contexts, lead to emergency calls for STEM education (El-Deghaidy, Mansour, Alzaghibi, & Alhammad, 2017; Kartal & Tasdemir, 2021; Wang, Charoenmuang, Knobloch, & Tormoehlen, 2020; Wang, Moore, Roehrig, & Park, 2011). Preparing scientists, technologists, engineers, and mathematicians for the future would help countries remain competitive in the growing global economy (Dong, Wang, Yang, & Kurup, 2020; Kartal & Dilek, 2021; Margot & Kettler, 2019; Wang et al., 2011). The need to prepare students for future STEM careers makes elementary and secondary education crucial to contribute to societies and economies in STEM fields (Margot & Kettler, 2019).

Considering the importance of STEM education, many initiatives and endeavors addressed preparing students with a well-rounded education. However, the instruction policies mainly focus on the content and pedagogy rather than the abilities needed to thrive in the 21st century. This leads to a dissonance between education policies, the training teachers receive, and the requirements and needs of the rapidly changing and complex world (Jamil, Linder, & Stegelin, 2018). STEM pedagogy may be considered an interdisciplinary approach that combines science, technology, engineering, and mathematics in a way that helps students to solve real-world problems using their mathematics and science knowledge through engineering design and technology (El-Deghaidy et al., 2017; Margot & Kettler, 2019). To achieve the goals of STEM implementations, teachers have a crucial role. Teachers are one of the most critical factors in implementing integrated STEM education (Dong et al., 2020; El-Deghaidy et al., 2017; Jamil et al., 2018; Margot & Kettler, 2019) and may either enhance or hinder students' development in STEM disciplines (Margot & Kettler, 2019).

STEM pedagogy requires a shift towards the student-centered project-problem-inquiry-based approaches that may differ from most teachers' training (Margot & Kettler, 2019). However, teachers may not feel prepared to train students to solve complex interdisciplinary problems (Wang et al., 2020) and may need guidelines or models to teach STEM in their classroom as many teachers lack knowledge and experience of STEM integration (Wang et al., 2011). Understanding teachers' understandings and implementations of STEM education demand revealing teacher beliefs firstly. Examining teacher beliefs and practices regarding STEM education may reveal which factors, such as teacher experience and knowledge, classroom environment, student, and district, affect these beliefs and practices (Buehl & Beck, 2014) and help understand and support the positive influences of teachers' beliefs on their STEM implementations (Jamil et al., 2018).

Teachers' attitudes and beliefs are strongly correlated to their behaviors and effectiveness in the classroom (Pajares, 1992). Teachers' knowledge, beliefs, and practices are interwoven. Teacher beliefs have a crucial role in determining how to promote teachers' STEM implementation, influence how teachers interpret the knowledge during their professional development (Jamil et al., 2018), and help to overcome instructional challenges to integrate STEM subjects (Dong et al., 2020). Unless teacher preparation programs or professional development programs influence teachers' underlying beliefs, it is not easy for these programs to lead to observable changes in teachers' behaviors (Feldon, 2007; Jamil et al., 2018). It may be helpful for policy-makers and school administrators to understand what teachers believe and what kind of challenges and barriers they report in implementing integrated STEM to facilitate the implementation and success of STEM education (Margot & Kettler, 2019). Therefore, more research regarding teachers' understandings and implementation of STEM integration is needed (Wang et al., 2011). This study focused on beliefs, motivational orientations, and implementations of teachers who implemented STEM in their teaching practices. Unpacking the beliefs and practices of teachers who implement STEM integration may guide the development of models or guidelines for teachers who wish to implement STEM integration.

Theoretical Frameworks

The study used STEM integration, teachers' beliefs, motivational orientations, and STEM implementations as theoretical frameworks.

STEM Integration

National Research Council (2014) stated that STEM integration requires students to use knowledge and skills from multiple disciplines within the context of complex phenomena or situations. STEM education removes the boundaries among STEM disciplines and integrates the disciplines with blurry boundaries into students' learning experiences (Vasquez, Sneider, & Comer, 2013). STEM education brings environmental, social, and economic problems from students' real contexts (Acar, Tertemiz, & Taşdemir, 2018), and students are supposed to apply their knowledge of science, mathematics, and engineering, collect, analyze, and interpret data, and cooperate with peers (Sanders, 2009). Students should be given the opportunity of rich and engaging experiences that foster their understanding of content in STEM disciplines (Wang et al., 2011) and engage them to think and work with peers creatively and critically (Morrison, 2006). STEM integration has the potential of promoting students' interest and motivation regarding learning STEM subjects and pursuing STEM careers (El-Deghaidy et al., 2017).

Even though STEM integration necessitates interdisciplinary teaching and collaboration, most teachers might have traditional training that focuses on teaching their disciplines in silos (Wang et al., 2020). The nature of STEM aligns with the interdisciplinary curriculum integration, and the traditional school structures mainly include hindrances for teachers to implement integrated STEM (Dong et al., 2020). Therefore, more research needs to focus on teacher beliefs and practices in implementing STEM to encourage the others who avoid teaching integrated STEM. Teachers' perceptions of how to teach integrated STEM and their perceived value of STEM integration on students' learning influence how they design and teach a STEM integration unit (Wang et al., 2011). The following sections are related to teachers' beliefs, motivational orientations, and implementations of STEM.

Teacher Beliefs about STEM

Teacher beliefs have the potential to guide teacher behaviors in class. However, it is worth noting that teachers' beliefs and practices depend on their contexts (Wang et al., 2020). Teacher beliefs about STEM education may vary by teachers' age, professional training, and teaching experience (Jamil et al., 2018). Beliefs about STEM include beliefs related to teaching STEM, including instruction, knowledge, and students (Buehl & Beck, 2014). In this study, we consider beliefs about STEM, including the beliefs about the nature of STEM, beliefs about the perceived value of STEM education on students' learning, and pedagogical beliefs regarding STEM education (Bender, Schaper, Caspersen, Margaritis, & Hubwieser, 2016; Hsu, 2016; Liu, 2011).

The nature of STEM integration requires making blurry the boundaries between STEM disciplines to develop students' knowledge and skills in these disciplines (Dong et al., 2020;

Wang et al., 2011). Breiner and colleagues (2012) stated that many teachers considered STEM integration to combine all four STEM disciplines. Similarly, Wang and colleagues (2011) also found that teachers are aware of the connections between STEM disciplines. However, teachers may focus on their disciplines rather than cross-disciplinary ideas (McNeill & Knight, 2013; Wang et al., 2020). For example, El-Deghaidy and colleagues (2017) reported that science teachers who participated in their study mostly defined integration as combining two disciplines: science and technology or science and mathematics. Teachers who attended a STEM professional development program and then integrated STEM into their classes stated that STEM disciplines were related naturally in the real world (Wang et al., 2011). Understanding the nature, pedagogy, and features of STEM education help teachers encounter lower levels of intrinsic challenges (Dong et al., 2020).

STEM integration should focus on problem-solving by developing, applying, and evaluating solutions to make students act as problem-solvers, innovators, inventors, logical thinkers, and technology literates (Kendall & Wendell, 2012; Morrison, 2006; Wang et al., 2020). Besides, engaging with STEM activities may increase students' interest in future STEM careers (Wang et al., 2011) and the content (El-Deghaidy et al., 2017; Jamil et al., 2018). Teachers who implemented STEM integration reported that STEM helped students think independently, communicate with peers about what they think, feel more confident in learning content, develop skills to work collaboratively, and feel more confident in learning science and mathematics (El-Deghaidy et al., 2017; Wang et al., 2011). In addition, STEM education motivates students to solve complex real-world problems and feel talented in STEM challenges (Margot & Kettler, 2019; Wang et al., 2011).

Teachers who valued STEM education also showed a high level of readiness for STEM education. Teachers with the positive perceived value of STEM on student learning are willing to engage their students with STEM activities (Margot & Kettler, 2019). In addition, some teachers reported that the increase in students' engagement in STEM tasks was because the activities were meaningful (Jamil et al., 2018). Teachers who have positive value beliefs regarding STEM education implement STEM in an interdisciplinary way (Dong et al., 2020).

Curriculum integration, such as STEM integration, aligns with constructivism and allows students to guide their learning (El-Deghaidy et al., 2017; Margot & Kettler, 2019; Wang et al., 2011). In other words, teaching integrated STEM requires providing students with the opportunities to connect their prior knowledge of STEM disciplines to real-world contexts, and students are encouraged to learn by doing. Teachers considered students' participation in hands-on application activities as necessary and beneficial in order to develop students' understanding of and interest in STEM (Margot & Kettler, 2019). As a curriculum integration, STEM integration should begin with real-world problems that make students focus on their knowledge and skills in all STEM disciplines (Wang et al., 2011). It also means using a project-based approach that leads students to use their content knowledge to solve problems (Margot & Kettler, 2019). Problem-solving is crucial to integrating engineering into science and mathematics content (Wang et al., 2011).

STEM integration requires teachers to adapt pedagogical approaches that focus on problem-solving, collaboration and cooperation, critical thinking, and innovation (Dong et al., 2020; Jamil et al., 2020). The STEM pedagogy is different from the traditional teaching that focuses on a single subject (Dong et al., 2020). Therefore, teachers should be skilled in employing student-centered pedagogies and encourage students to solve ill-defined real-world problems by deepening their knowledge and skills in STEM disciplines (Margot & Kettler, 2019).

Teachers' Motivational Orientations regarding STEM

Motivational orientations may be defined as the overall goals, motives, or values teachers attribute to their teaching abilities (Bender et al., p. 2016). The motivational orientations in this study include teacher enthusiasm and efficacy beliefs regarding STEM education. The enthusiasm for teaching STEM refers to the degree of teachers' positive experiences during STEM teaching (Kunter, Frenzel, Nagy, Baumert, & Pekrun, 2011). Enthusiasm may be regarded as teacher interest and intrinsic motivation in teaching STEM subjects (Bender et al., 2016). Intrinsic motivation has two dimensions called topic-related dimension and activity-related dimension (Eccles & Wigfield, 2002). The topic-specific dimension is related to STEM, and the activity-related dimension is related to teaching STEM. For example, a motivating teaching style, expressing their interest in the subject, or addressing the value of the subject are the indicators of teacher enthusiasm (Kunter et al., 2011; Bender et al., 2016). We may also define teacher enthusiasm for STEM as teachers' willingness to stay up to date regarding innovation in STEM and to motivate themselves to learn more about STEM, based on Bender and colleagues (2016).

The enthusiasm and motivation of teachers are among the most crucial factors that increase students' interest and motivation (Long & Hoy, 2006; Roberts, 2002) and help teachers feel more confident and comfortable implementing an integrated STEM curriculum (Stohlmann, Moore, & Roehrig, 2012). Furthermore, teachers who show interest in the subject make their students increase their involvement in the subject-related activities (Kunter et al., 2011). Teachers with a high level of enthusiasm regarding STEM are supposed to invest more time and effort in teaching STEM and have higher endurance to face the challenges in their STEM implementations (Eccles & Wigfield, 2002).

The other construct of motivational orientation in this study is teacher efficacy beliefs. Considering the definition of Ashton (1984, p. 28), we define the teacher efficacy regarding STEM as "the extent to which teachers believe that they can affect their students' performances in STEM." In addition, teacher efficacy regarding STEM refers to using various instructional strategies, engaging student participation, and managing the classroom when teaching STEM subjects (Tschannen-Moran & Hoy, 2001). Teacher efficacy beliefs increase teachers' willingness to implement STEM curriculum (Margot & Kettler, 2019). Low efficacy beliefs regarding integrated STEM education make teachers spend less time planning and execute STEM activities (Tschannen-Moran & Hoy, 2001).

Teachers' efficacy beliefs regarding STEM education are positively related to their knowledge of STEM content (Nadelson et al., 2012). Having sufficient knowledge makes teachers feel that they can contribute to students learning (Margot & Kettler, 2019) and increases teachers' abilities to plan and conduct complex lessons that address different students' needs (Jamil et al., 2018). Attending professional development programs regarding STEM increases teachers' efficacy beliefs (Nadelson et al., 2012).

STEM Teaching Practices

Moore and colleagues (2014) proposed six tenets for effective K-12 STEM integration. These major principles for quality in STEM education refers to (a) including science and mathematics content, (b) employing student-centered pedagogy, (c) situating lessons in an engaging and motivating context, (d) using engineering design, (e) allowing students to learn from their mistakes, and (f) promoting teamwork (Margot & Kettler, 2019, p.2). However, STEM integration often includes the science and mathematics content with little integration of engineering and mathematics (Moore, Glancy, Tank, Kersten, & Smith, 2014; Wang et al., 2020). Teachers mostly use their main discipline to integrate STEM subjects and connect STEM disciplines (Dong et al., 2020).

STEM pedagogy makes teachers guide students in examining the problems, trying on and evaluating solutions, and realizing that there is more than one solution in STEM contexts. Allowing students to evaluate their solutions to real-world problems and improve their solutions is a part of the cyclic process in engineering design (Margot & Kettler, 2019). An inquiry-based, project-based, and problem-based instruction helps teachers achieve STEM education goals such as deepening students' content knowledge, increasing their interest in STEM careers (Margot & Kettler, 2019). Teachers should use questioning to make students think critically for innovation and increase their understanding of content and concepts.

Additionally, teachers may have challenges and impediments that hinder them from implementing integrated STEM activities, as Moore and colleagues (2014) suggested. Teachers' challenges when integrating STEM subjects are related to instructional materials and teaching practices (ByBee, 2013). The lack of content and pedagogical knowledge hinders teachers in integrating other STEM subjects (Dong et al., 2020; Kurup, Li, Powell, & Brown, 2019; Wang et al., 2020).

Teachers may have difficulties in interdisciplinary collaboration because of the lack of content knowledge of other disciplines and the lack of interdisciplinary teaching experiences in their preservice teacher education (Dong et al., 2020; Wang et al., 2020). External factors also influence teachers' interdisciplinary STEM collaboration (Wang et al., 2020). These factors might be specified as school structure and organization structure, the impact of traditional exams, and the lack of instructional resources and materials regarding STEM (Dong et al., 2020).

Teachers may have difficulties in integrating technology in their multidisciplinary teaching. For example, Margot and Kettler (2019) stated that the difficulties in integrating technologies might stem from teachers' perceptions of technology, believing technology is just hardware (p.10). Similarly, El-Deghaidy and colleagues' (2017) participants perceived technology as including just the Internet and search engines. The lack of technology and engineering may stem from teachers' lack of knowledge, skills, and confidence in these disciplines (Bybee, 2013; Dong et al., 2020; Wahono & Chang, 2019; Wang et al., 2020). Teachers addressed the importance of professional development, especially in implementing engineering for the integrated STEM curriculum (Margot & Kettler, 2019).

Professional development programs may enhance teachers' perceptions about STEM and help teachers integrate STEM subjects into their content. However, how they integrate STEM subjects is associated with their beliefs about the value, nature, and purpose of the STEM integration (Wang et al., 2011). It may be beneficial for teachers to attend a professional development program to help them learn how to integrate STEM subjects and increase their efficacy beliefs and confidence (El-Deghaidy et al., 2017). The more teachers can work in teams to implement STEM, the more they learn from each other and feel confident in interdisciplinary collaboration (Wang et al., 2020).

STEM teachers' beliefs and practices have been a concern of interest for researchers as teacher beliefs influence teacher practices that either promote or hinder students' interest in STEM disciplines and future careers. Most of the research is large-sample designs investigating the relationships among teacher beliefs, practices, knowledge, intrinsic challenges, and the perceived teaching competence (Dong et al., 2020; Park, Dimitrov, Patterson, & Park, 2017; Smith, Rayfield, & McKim, 2015; Song & Zhou, 2021). Researchers investigated teacher beliefs and practices of participants by employing qualitative techniques after attending professional development programs (Han, Yalvac, Capraro, & Capraro, 2015; Herro & Quigley, 2017; Jamil et al., 2018; Ring, Dare, Crotty, & Roehrig, 2017; Wang et al., 2011; Wang et al., 2020). However, El-Deghaidy and colleagues (2017) examined science teachers' existing views about STEM education and the challenges of STEM integration. This study investigated teacher beliefs and practices without arranging any professional development programs. The participants' backgrounds demonstrated various STEM training experiences. We aimed to investigate the natural context of teachers' beliefs and practices. For example, this is a question that the findings of this study might contribute: *What did motivate those who did not get any STEM training to implement STEM activities?* Additionally, the participants' subjects are science, mathematics, and primary education. The variety of subjects might provide insight into how different subject grades' teachers implement STEM activities. The research questions that guided the study are as follows:

1) What are participants' beliefs and motivational orientations regarding STEM education?

2) How do participants implement STEM subjects in their teaching practices?

Method

Research Design

This study aims to explain in-depth and extensively "how" and "why" teachers implement STEM subjects within their real-world contexts without researchers' control over behavioral events (Stake, 2006; Yin, 2018). Therefore, we used a two-phase multiple case study that provides an insight into understanding a phenomenon, population, or circumstances by examining multiple cases together (Stake, 2006). The first phase focuses on analyzing data obtained from each participant (as a case) individually, and the second attempts to reveal the similarities and differences between cases. In other words, we created patterns and themes and then compared these patterns and themes within cases. Comparing cases provide researchers to look in-depth at the similarities and differences and help them identify the factors that explain the differences (Patton, 2015).

Role of the Researchers

Researchers' experiences and preconceptions influence how they interpret the data (Ottenbreit-Leftwich, Glazewski, Newby, & Ertmer 2010). Therefore, it is worthwhile to address the role of researchers. Researchers discussed the findings, explanations, and suggestions critically, and this step is an avenue to avoiding researchers' bias that influences the research process (Merriam, 1998; Yin, 2018). Researchers have knowledge and experience regarding case studies and teacher beliefs, are interested in STEM education, and are familiar with STEM education literature. General guidelines and the experiences of researchers and other colleagues lead the research process. Researchers were familiar with the data obtained from the interviews, participated in the data analysis, and discussed until reaching a consensus to avoid any judgments regarding participants' responses.

Participants

The number of cases to provide enough information regarding the phenomenon of interest should be four to ten (Stake, 2006). Participants were selected by employing purposeful sampling to maximize variety and increase the range of data, and they were six teachers from primary school to middle school levels (Morgan, 1997; Patton, 2015). Researchers aimed to obtain information about the phenomenon (STEM implementation) from participants with specific characteristics by employing purposeful sampling (Miles & Huberman, 1994). However, it is not easy to generalize the findings of participants selected through purposeful sampling to a larger population (Onwuegbuzie & Collins, 2007). The participants who voluntarily agreed to participate in the study were highly willing to implement STEM subjects in their teaching practices and had experiences integrating STEM. The participants were three female and three male teachers. Two of them were mathematics teachers, two were science teachers, and two were primary teachers. The demographics of participants are given in Table 1.

Table 1. The Demographics and Background of Participants

	Mathematics Teachers		Science Teachers		Elementary teachers	
	Selcen	Aziz	Bahar	Uğur	Ahsen	Kaan
Gender	Female	Male	Female	Male	Female	Male
Educational Background	Ph.D. candidate	Master degree candidate	Ph.D. candidate	Master degree	Ph. D.	Master degree
Years of Teaching Experience	10	11	8	19	11	13
STEM Training Participation	No	Yes	Yes	Yes	Yes	Yes
Years of Experience STEM Teaching	2	3	4	7	3	3
Grades	4th, 5th, 6th, 7th, and 8th	5th, 6th, 7th, and 8th	5th, 6th, 7th, and 8th	5th, 6th, 7th, and 8th	1st-5th 7th and 8th	1st-5th 1st-4th
Subject	Mathematics Science English	Science Mathematics Mathematical Practices	Science (especially chemistry subjects) Mathematics	Science Health and Environment	All subjects in primary school Technology and Design	All subjects in primary school
Number of students in classes	5-8	20-25	5-8	25-30	25-30	25-30

Roles outside of teaching	Project consultation STEM activities consultation Quiz coordinator	Model aircraft training consultation	Dance Theater education consultation Project coordinator	Training of educators MoNE-R & D coordinator Community service practices coordinator Project coordinator Administrator	Project coordinator	Project coordinator Administrator

It is worthwhile to specify some circumstances that do not exist in the table. For example, Selcen and Bahar worked at the "Science and Art Center," which admits students after a diagnostic test. The Science and Art Centers aim to develop gifted preschool, primary, middle school, and high school students' talents regarding art, music, and cognition as an adds-on students' formal education. The number of students in the classrooms varied from five to eight. The teachers in this school reported that the distribution of gender is almost equal.

Aziz is a mathematics teacher, but he works towards a master's degree in science education. He explained this choice as a result of his interest in STEM education. He consulted for model aircraft training, and he reported that he focused on the science and mathematics concepts in these training. In addition, the school he worked at had computer laboratories and smartboards.

Uğur has been an administrator for almost 15 years. He participated in many national and international projects. For example, Uğur contributed to the "Science Fair" sponsored by The Scientific and Technological Research Council of Turkey annually. In addition, he joined the STEM training of trainees supported by the European Union. With the support of an international foundation, he established workplaces regarding STEM, Robotic Coding, Music, Painting, and Drama and made it easy for students and teachers to access these resources. He still trains his colleagues about STEM education.

Ahsen participated in many training regarding STEM education and taught "Technology and Design" for the last nine years. However, her school lacked resources such as technology and design workplace or laboratories. Instead, there are smartboards in the classrooms. Kaan is especially interested in robotics coding. He taught all subjects in primary grades and reported that he integrated STEM subjects into science lessons. He worked at rural schools until now; therefore, he mostly lacked resources. However, he provided computers, scanners, printers, and projections with the support of a national funding project.

Data Collection and Analysis

Data collection focused on capturing a deeper understanding of teacher beliefs about STEM and STEM teaching, their motivational orientations to teaching STEM, and their teaching practices, including supports and challenges they face in their STEM implementations. The internal concepts such as values and beliefs might be best explicated through interviews (Ottenbreit-Leftwich et al., 2010). Therefore, data were collected via one-on-one in-depth interviews. A semi-structured interview protocol with probing questions was used to ensure consistency during interviews. We aimed to comprehend teachers' beliefs and motivational orientations, how they implement STEM activities in their classrooms, and their challenges in integrating STEM in detail using the protocol and follow-up questions. Providing participants the flexibility and making them feel confident are the main goals to capture as much as possible details regarding participants' experiences, espoused beliefs, challenges, and needs. Two researchers visited one participant at his school and interviewed him. However, the other participants were interviewed online. The interviews were audio and video recorded with the consent of participants. The interviews lasted approximately 45 minutes.

The semi-structured interview protocol focused on the following themes: (i) teacher beliefs about the nature of STEM, (ii) teachers' pedagogical beliefs about STEM education, (iii) teachers' perceived value beliefs about STEM education on student learning, (iv) teachers' motivational orientations (such as efficacy and enthusiasm), and (v) teachers' STEM implementation, including teaching methods they employed, the challenges they faced, and so on. The researchers developed the questions (Appendix) based on literature regarding teacher beliefs, motivational orientations, and STEM implementations (Bender et al., 2016; Hsu, 2016; Moore et al., 2014).

Interviews were transcribed verbatim, and all researchers read the transcripts without making any analysis and interpretation. Open coding, axial coding, and selective coding were used to identify patterns among teachers' beliefs. Firstly, all researchers read the data to verify the data accuracy. Then, important phrases were highlighted, and a code was assigned to these highlighted phrases. Next, the codes were categorized into beliefs, motivational orientations, and teaching practices. Then subcategories were specified for beliefs, motivational orientations, and teaching practices. For example, the subcategories for teacher beliefs were beliefs about the nature of STEM, pedagogical beliefs regarding STEM education, and the perceived value of STEM education on students' learning. The interviews were analyzed based on the literature regarding teacher beliefs and motivational orientations (Bender et al., 2016; Hsu, 2016). Next, teachers' implementations were inscribed using narratives, and then the pieces of evidence of six tenets in STEM education (Moore et al., 2014) were searched. Finally, a codebook for data analysis was created to help connect findings to the literature (see Table 2).

Table 2. Codebook Used to Analyze Data

Theme	Category	Definition
Teacher beliefs	Beliefs about the nature of STEM	Beliefs about science, technology, engineering, and mathematics individually and the connections between these disciplines
	The perceived value of STEM education on student learning	Beliefs about the effect of the STEM subjects on instruction and students' learning
	Pedagogical beliefs about STEM education	Beliefs related to teaching STEM (student-centered pedagogy, problem-based approach, inquiry-based instruction etc.)
Motivational orientations	Efficacy beliefs regarding STEM subjects and teaching STEM	Beliefs about teachers' abilities to integrate STEM disciplines and beliefs about profession-related outcome expectancy
	Enthusiasm for STEM subjects and teaching STEM	Teachers' interest, joy, excitement, and intrinsic motivation for STEM subjects and teaching STEM
Teaching practices	Including science and mathematics content	
	Employing student-centered pedagogy	

An engaging and motivating learning environment
Using engineering design
Allowing students to learn from their mistakes
Emphasizing cooperative learning

The categories and subcategories were extracted by breaking apart and putting the data back together (Corbin & Strauss, 2014). Then, to identify the recurring themes, we compare the themes among the participants. Lastly, we use selective coding by determining core categories that are related to each other. The process of creating codes was performed by each researcher individually. Then, the created codes were cross-checked among the researchers.

The reports of the data analysis included two sections that are (i) individuals' descriptive narratives regarding their beliefs, motivational orientations, and experiences, including quotations and (ii) cross-case comparisons. In addition, quotes from interviews were given to support findings. Finally, member checking was used to make participants confirm the interpretations and findings obtained from their interviews.

Issues of Validity and Reliability

"Credibility" and "confirmability" establish the "trustworthiness" that is the standard of evaluating qualitative findings (Lincoln & Guba, 1985). Credibility is gained through employing multiple data sources (interviews, lesson plans). On the other hand, confirmability is ensured by multiple researchers working together in the whole process of the study. Researchers analyzed data independently, compared their emerging codes and themes, and discussed until reaching a consensus about data analysis and interpretation. Identifying the unclear codes by researchers is a valuable avenue to ensure internal consistency (Fowler, 2014).

Participants were informed about their privacy and the pseudonyms given to them. This step is crucial in building trust with participants. In addition, member checking was employed to ask participants to confirm the findings obtained from interviews. Minor errors in demographics were corrected through participants' suggestions. Besides, participants did not report any disagreement regarding the findings obtained from their interviews.

Results

Teacher Beliefs about STEM

This section demonstrates the findings regarding teachers' beliefs about the nature of STEM, the perceived value of STEM education on students' learning, and beliefs about teaching STEM. Table 3 demonstrates teacher beliefs about the nature of STEM.

Table 3. Findings related to Teacher Beliefs about the Nature of STEM

		Mathematics Teachers		Science Teachers		Primary Teachers	
		Selcen	Aziz	Bahar	Uğur	Ahsen	Kaan
Beliefs about the Nature of STEM	Connected to daily lives	√	√	√	√	√	√
	Requires problem-solving		√	√	√	√	√
	Integration of disciplines	√	√	√	√	√	√
	The connectedness of disciplines	√			√	√	
	The integration of science and mathematics	√		√		√	
	Integrating STEM disciplines with social sciences such as art	√		√	√		
	STEM is essential for the competitive world		√		√		
	Creating a product		√		√		√
	Project-based		√		√	√	√
	Robotics		√	√	√		
	21st-century skills			√	√		
	Appropriate to integrate into science lessons					√	√

Teachers perceived that STEM integrates multiple disciplines to solve a problem and is related to real-world contexts. In addition, teachers addressed that STEM develops students' skills and knowledge when working to solve a problem. For example, Ahsen defined STEM as follows:

> *"STEM education employs real-world problems. For example, the students faced a problem on his farm. To solve this problem, he/she uses the engineering design cycle, defines the* problem*, investigates to solve the problem. He/she need to use scientific and mathematical knowledge to develop a solution. STEM combines these disciplines within the context of a problem."*

Although all teachers were aware of the nature of STEM as the integration of multiple disciplines, three of them emphasized that STEM education mainly refers to the integration of science and mathematics. However, Uğur stated that STEM education should not be allocated to only one subject, such as science and mathematics. He defined that STEM education as a valuable avenue that helps students to achieve learning outcomes across disciplines. In addition, Aziz taught science and mathematics lessons for three years; thus, he had interdisciplinary teaching experience. He emphasized that STEM education is different from integrating science and mathematics curriculum and it requires project-based approaches.

Selcen and Bahar also explained that integrating disciplines should not be limited to science, technology, engineering, and mathematics; instead, social sciences such as history and geography should be integrated. Therefore, Bahar said that:

> *"I did not define STEM as integrating science, technology, engineering, and mathematics based on the acronym. Instead, I think that social sciences such as geography should be included. For example, my students made a shadow clock that requires integrating the knowledge of geography as well as the knowledge of science and mathematics."*

It is also surprising that primary teachers reported that science lessons have the most appropriate learning environments to integrate STEM subjects. They thought that real-world problems were situated in science contexts. Furthermore, Kaan stated that primary students had problems with mathematics. He thought that the more mathematics in STEM activities increased, the more students felt uncomfortable with STEM activities.

There are some findings not included in the table to avoid redundancy. For example, Aziz and Ahsen were the ones who mentioned engineering when defining STEM. Aziz said, *"STEM disciplines are essential for especially engineers or individual who think like an engineer."* In summary, teachers commonly defined that STEM education includes solving real-world problems that consist of different disciplines and requires students to use the knowledge and skills of these disciplines. Table 4 demonstrates teachers' beliefs about the perceived value of STEM education on students' learning.

Table 4. Findings related to Teacher Beliefs regarding the Perceived Value of STEM Education on Students' Learning

		Mathematics Teachers		Science Teachers		Primary Teachers	
		Selcen	Aziz	Bahar	Uğur	Ahsen	Kaan
The Perceived Value of STEM Education on Students' Learning	Enhances students' interest	√	√	√	√	√	√
	Motivates students	√	√	√			
	Promotes students' participation	√		√	√	√	
	Makes students apply knowledge into real-world contexts	√			√	√	
	Helps students explore their talents	√		√	√		√
	Promotes collaborative learning		√		√	√	
	Makes students guide their learning			√	√	√	
	Does not ensure equal participation among students				√	√	√
	The effect of socio-culture		√		√		√
	Promotes thinking skills			√			√
	Gender	√	√		√	√	√
	Promotes students' endurance in facing challenges				√		
	Promotes learning	√				√	

As seen from the table, all teachers believed that STEM education increases students' interest in STEM content and careers. Enhancing students' motivation and participation were other perceived values of STEM education. Aziz said, *"Students' motivation increases when they contribute to the solution of a problem."*. In addition, Bahar explained that the difference between STEM education and traditional teaching is crucial for increasing students' interest and motivation.

The majority of teachers expressed that STEM guides students to discover their talents. On the other hand, Selcen and Ahsen stated that STEM activities help low achieving students see they can do it. According to these teachers, students with low achievement scores might realize that they could do science or mathematics during STEM activities. For example, Selcen told about her student who did not like writing and did not have good grades. She added that STEM activities made her and the student realize the student's performance in problem-solving and reasoning processes. The following statement exemplifies how students realize their self-concepts:

> *"Students get happy and excited when they do it (STEM activities), and then the students with low grades participate in activities. As a result, teachers may see promising performances from students they did not expect."*

However, teachers reported that STEM education might not ensure equal participation of students. Respondents explained the reason as students' different talents and skills. The participants emphasized the importance of teamwork in minimizing the effect of different talents and skills as follows:

> *"Students might have difficulties when they lack knowledge (mathematics or science) regarding the STEM activity. However, the students have the opportunity to learn from their peers in the teams. The teamwork is crucial in providing students benefit from STEM activities." (Ahsen)*

Kaan added that STEM does not only promote students' interest and motivation, and it also promotes students' life skills. He stated, *"Students learn by expressing themselves, justifying their ideas, and self-assessing during STEM activities."*

Teachers disagreed on the effect of gender in STEM education. Selcen and Bahar believed that they did not see any difference in terms of gender. However, other teachers reported that girls are less interested and confident in STEM activities than boys. Ahsen stated that girls mainly have difficulties in engineering. Kaan explained that this might be because families do not encourage their girls for STEM careers. As an attractive finding, Uğur proposed that gender influenced students' performance and interest, especially in rural schools.

It is possible to say that teachers had positive value beliefs about STEM education on students' learning. In addition, they also explained why they believed that STEM education has positive effects on students' learning. According to teachers, STEM education has beneficial effects because (i) it makes students realize that the subjects are not complex, (ii) it promotes the interaction between students and teachers and among students, (iii) it makes students feel what they need to know to solve the complex real-world problems, and (iv) promotes students 21st-century skills. Table 5 demonstrates findings related to beliefs regarding teaching STEM.

Table 5. Findings related to Beliefs regarding Teaching STEM

		Mathematics Teachers		Science Teachers		Primary Teachers	
		Selcen	Aziz	Bahar	Uğur	Ahsen	Kaan
Beliefs Regarding Teaching STEM (Pedagogical Beliefs)	Connecting new knowledge to prior knowledge	√			√		
	Teamwork	√	√	√	√		√
	Focus on main discipline	√					
	Evaluation	√					
	Being the authority		√				
	Learning by doing	√		√	√	√	√
	Students' investigation of knowledge				√	√	
	The transition from teacher-centered pedagogy to student-centered pedagogy	√					
	Allowing students to think creatively		√				
	Allowing students to guide their learning		√	√	√		

Teachers emphasized the importance of the opportunity to learn by doing STEM activities. The majority of them addressed that students learn the content and promote the skills such as problem-solving, reasoning, communication, and creativity. A teacher quote is as follows:

> *"Teachers should not make students only read and write. They should allow their* students *to engage with the activity; then students learn what they need to learn by doing and engaging with the activity." (Uğur)*

Teachers underlined that STEM teaching should connect students' prior knowledge to the new one. This would also allow students to guide their learning. Thus, it seems that teachers' beliefs about teaching STEM align with the STEM pedagogy that requires a student-centered approach. Participants also mentioned the importance of teamwork to achieve the goals of STEM education. Kaan explained how teamwork supports STEM education as follows:

> *"When* students *are working crowded groups, it may be difficult for the teacher to see who do what. However, allowing students to work in small groups promotes students' investigation of knowledge."*

Different from other teachers, Selcen addressed two more points regarding STEM teaching. She reported that her main focus is to deliver mathematics content primarily on her STEM activities. She also emphasized evaluating STEM activities and reported that her teaching philosophy shifted from teacher-focused to student-centered approaches during STEM teaching experiences.

Besides, Aziz insisted that the teacher should be the authority to spend in-class time effectively. His idea aligns with the traditional teaching that assumes the teacher is the only authority in the classroom. However, STEM pedagogy requires student-centered approaches. This dissonance highlights the importance of time management in STEM activities for teachers.

Teachers' Motivational Orientations regarding STEM

Teachers' motivational orientations regarding STEM consist of teachers' enthusiasm and efficacy beliefs regarding STEM and teaching STEM. Table 6 demonstrates teachers' enthusiasm regarding STEM education.

Table 6. Teachers' Enthusiasm regarding STEM Education

		Mathematics Teachers		Science Teachers		Primary Teachers	
		Selcen	Aziz	Bahar	Uğur	Ahsen	Kaan
Enthusiasm and Interest regarding STEM Education	Students' motivation and excitement	√		√	√	√	√
	Students' achievement and understanding		√		√		√
	The expectation of administrators	√					
	Parent feedback			√			
	Role models						√
	Willingness to stay up to date	√			√		√
	Collaboration to learn more about other disciplines	√					
	Participating in professional development programs with a great excitement		√				

All participants reported their enthusiasm and interest regarding STEM educations. The enthusiasm made them participate in professional development programs or use STEM activities in their teaching practices with great excitement. The following statements underpin this finding:

> *"I participated in the professional development programs with a great excitement and willingness since I thought that they are essential for my development." (Aziz)*
>
> *"I use STEM activities willingly, and I have the joy of doing this." (Bahar)*

To Kaan, enthusiasm is an influential factor that encourages teachers to implement STEM. Teachers stated that enthusiasm and wonder about STEM promote teachers' persistence in teaching STEM. Ahsen said, *"If a teacher is excited about STEM, he/she will persist in using STEM activities."*

In addition, interviews revealed the sources of the teacher enthusiasm and interest to integrate STEM. Most teachers stated that students' high level of motivation and interest in their lessons also made them feel excited and interested in STEM and promoted their motivation to carry on STEM activities. For example, Selcen said, *"Students are interested in these activities, and they get excited after creating a product. Seeing them happy, excited, and interested also makes me happy."*

It is worth noting that female teachers focused on students' affective characteristics such as interest and motivation, and male teachers focused on students' cognitive characteristics such as understanding and achievement. Only students' affective or cognitive characteristics did not make teachers have positive experiences when implementing STEM activities. Besides, positive feedback from parents, observing role models in STEM education, and the support of administrators were also factors that enhance teacher enthusiasm and interest. Table 7 is related to teachers' efficacy beliefs regarding STEM education.

Table 7. Teachers' Efficacy Beliefs regarding STEM Education

		Mathematics Teachers		Science Teachers		Primary Teachers	
		Selcen	Aziz	Bahar	Uğur	Ahsen	Kaan
Efficacy Beliefs regarding STEM Education	High confidence and efficacy		√		√		√
	Developing confidence and efficacy	√		√		√	
	Engaging students' interest	√	√			√	
	Using various instructional strategies	√					

Teachers' confidence and efficacy levels might be categorized into two groups: (i) high confidence and (ii) evolving confidence. The male teachers expressed that they felt confident with STEM disciplines and teaching STEM. For example, Uğur reported that the training he took and gave and the projects increased his confidence. Similarly, Kaan stated that the master's education and his interest in technological innovations and design made him feel more efficient and confident than before. In addition, Aziz expressed that using Arduino in teaching practices increased his confidence with STEM activities.

Female teachers described that they had a moderate level of efficacy and confidence in STEM teaching. The most reported source of the efficacy beliefs is mastery experiences. All teachers said that the more they implemented STEM activities, the more their efficacy beliefs increased; because they realized that they could teach STEM subjects.

The other aspect of teacher efficacy that participants mention is engaging students' interest. The majority of teachers emphasized using open-ended and engaging questions to spark students' interest in the subject.

Teaching Practices

The characteristics of quality in K-12 STEM education proposed by Moore and colleagues (2014) were the main focus of interest to analyze teaching practices. Teachers' STEM teaching practices were investigated based on their descriptions of how they implemented STEM activities. Additionally, challenges were also examined. Table 8 demonstrates teachers' teaching practices.

Teachers' reported teaching practices seem promising since their described STEM implementation mostly aligns with the quality principles in STEM education. Most teachers reported that they had integrated the science and mathematics content; however, Kaan stated that mathematics made students more anxious. This may be why his interview did not reveal the pieces of evidence of mathematics integrations. All teachers mentioned that they focused on students' learning by doing and guiding their learning. For example, Selcen emphasized that she drew attention to connect their prior knowledge to new knowledge. Employing real-world problems is remarked by all participants. They considered the potential of real-world problems to spark all students' interests.

Teachers created motivating and engaging learning environments in different ways. For example, Selcen reported that she used concepts or phenomena that are of interest to students. Aziz said that he used open-ended engaging questions to make students think about the subject. To participants, an engaging and motivating learning environment is essential to increase students' participation in activities.

Table 8. Teachers' Teaching Practices

		Mathematics Teachers		Science Teachers		Primary Teachers	
		Selcen	Aziz	Bahar	Uğur	Ahsen	Kaan
Teaching Practices	Including science and mathematics content	√	√	√	√		
	Employing student-centered pedagogy	√	√	√	√	√	√
	Situating lessons in an engaging motivating context	√	√	√	√	√	√
	Using engineering design	√	√	√	√	√	√
	Allowing students to learn from their mistakes				√	√	
	Promoting teamwork	√	√	√	√	√	√
	Attempts to increase students' interest in STEM careers	√	√	√	√	√	√
	Challenges						
	The competitive school culture		√	√	√		
	The intense curriculum	√					
	The lack of collaboration	√		√			
	The lack of professional development			√		√	
	The lack of instructional materials	√					

Teachers have mentioned that they valued teamwork and, therefore, employed collaborative instructional strategies that allow students to work together, think critically, communicate to justify ideas and create products. Figure 1 includes screenshots from teachers' STEM implementations. Uğur emphasized how teamwork promoted STEM education as follows:

> *"Students developed their communication skills in these teams. They learned to share ideas, materials, etc. They learned creating a product together."*

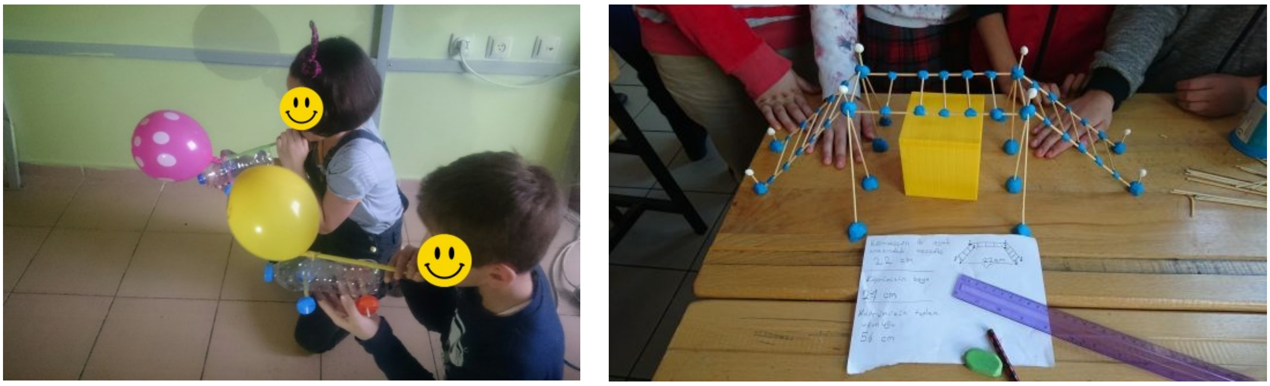

Figure1. Screenshots from Teachers' STEM implementations

Only two teachers reported that they guide their students to realize their mistakes and learn from these mistakes. Ahsen stated that she waited for students to realize what went wrong and how to correct it. Additionally, Uğur mentioned that mistakes help students to understand the subject better. Another promising finding is that all participants attempted to encourage and guide students for future STEM careers.

Teachers also reported some challenges when implementing STEM subjects. The table shows that the competitive school culture that focuses on standard-based testing more than skills, talents, and understanding makes teachers feel pressure to deliver the intense curriculum. In addition, as a result of high-stakes testing, administrators or parents might not appreciate STEM activities and, unfortunately, consider these activities as time-wasting. Therefore, teachers reported that they might lose their persistence in STEM implementations. On the other hand, the lack of knowledge of the out-of-main discipline and the lack of professional development that focuses on modeling STEM integration seemed to hinder teachers' STEM implementations. Moreover, even though teachers wish to get support from the other disciplines' teachers, they might experience a lack of collaboration.

Discussion and Conclusion

This study investigated the beliefs, motivational orientations, and teaching practices of teachers who implemented STEM activities in their natural settings of classrooms. Six teachers were selected through purposeful sampling, and they participated in the study. Data was collected via in-depth one-to-one interviews. Teachers' beliefs about the nature of STEM education, beliefs about the perceived value of STEM education on students' learning, beliefs about teaching STEM, enthusiasm and interest, efficacy beliefs, and teaching practices were the focus of the data analysis.

Participants mentioned that STEM education brings real-world problems and supposes students to solve them using their mathematical and scientific knowledge with technological and engineering design processes. This finding underpins the results of Breiner and colleagues (2012) and Wang and colleagues (2020). However, it is seen that all of them did not integrate all four disciplines when they were talking about their teaching practices. For example, mathematics teachers reported that their focuses were mainly on their discipline. Thus, it is possible to say that these teachers have an interdisciplinary understanding of STEM; but their practices primarily align with the multidisciplinary understanding of STEM. Typically, teachers might pay more attention to their disciplines (McNeill & Knight, 2013).

On the other hand, primary teachers reported that science lessons provide the most appropriate learning environment for STEM education. One teacher explained that students' mathematics anxiety makes him avoiding integrating mathematics into his STEM implementations. This may be because teachers lack knowledge of other disciplines, and the collaboration among teachers with different disciplines may not be sufficient (Dong et al., 2020; Wang et al., 2020). Thus, these teachers reported a lack of collaboration.

All teachers had positive value beliefs about STEM education on students' learning. For example, they mentioned that STEM education increases students' interest and motivation, and participation in activities helps students explore their self-performance and encourages them to share their knowledge and ideas in their teamwork. Many research mentioned these benefits in the literature (El-Deghaidy et al., 2017; Jamil et al., 2018; Margot & Kettler, 2019; Wang et al., 2011; Wang et al., 2020). Consistently with these positive value beliefs, teachers reported that they allowed their students to work in groups. The increase in students' participation, motivation, and interest also promoted their enthusiasm and excitement to integrate STEM subjects. Thus, we can say that there is a mutual relationship between students' interests and teachers' excitement that means an increase in one leads to an increase in the other. Jamil and colleagues (2018) argued that students participated in STEM activities since they perceived these activities as meaningful. Consistently with these findings, teachers explained that students like engaging with STEM activities since the activities are related to the real world. To teachers, the connectedness of STEM activities to the real world helps students make sense of the content in the STEM activities.

Teachers also discussed the effect of gender on students' STEM learning. The teachers who teach gifted students reported that they did not observe any difference in participation and interest between girls and boys. Primary teachers thought that there might be a slight difference because of the students' different interests. However, the teacher who worked at a rural school said that girls might have difficulties because of the lack of technological background.

It is promising to see that teachers' beliefs about teaching STEM align with the student-centered pedagogy. For example, teachers emphasized the importance of students' guiding learning and added that STEM activities promote students to learn by doing. In addition, Margot and Kettler (2019) found that students' participation in hands-on activities connects their prior knowledge to new knowledge and increases their interest and motivation. Teachers' reported practices include employing student-centered pedagogies, engaging students' interest in STEM, and promoting teamwork. However, considering the principles suggested by Moore and colleagues (2014), teachers' STEM implementations lack guiding their students to learn from their mistakes. Only two teachers referred to the role of students' mistakes in learning. It is also seen that participants had constructivist beliefs before they implemented STEM, and these constructivist beliefs seem to underpin their STEM implementations.

All participants reported high enthusiasm and interest in STEM subjects. In addition, as reported in the literature (Bender et al., 2016; Kunter et al., 2011), the teachers stated their interest in STEM, their motivating teaching style, and their positive perceived value of STEM education many times in the interviews. They described many factors that promoted their enthusiasm. The benefits of STEM education for students and increased students' interest and engagement were the most commonly reported factors that promoted teacher enthusiasm.

Teachers' efficacy beliefs mainly seem to influence teachers' decisions to what extent they integrate technology into their STEM implementations. Literature includes much research that refers to the lack of technology integration in STEM activities because of teachers' lack of knowledge, skills, and confidence (Bybee, 2013; Dong et al., 2020; Wahono & Chang, 2019; Wang et al., 2020). In addition, teachers reported that their efficacy beliefs regarding STEM increased over time. The more their STEM teaching experience increased, the more comfortable and efficient they felt.

It is not easy to generalize the findings of this study to other populations. However, the results might provide insight into findings regarding similar participants to compare similarities and differences. It is also worthwhile noting the limitations of the study. The classroom observations were not conducted because of online teaching as a result of the COVID-19 pandemic. Teachers' teaching practices were described based on the participants' interviews. The absence of any action or feature in the teaching practices does not mean that participants did not perform that action.

Recommendations

The results show that enthusiasm and interest are reported as essential factors to integrating STEM subjects. However, efficacy beliefs seem necessary to sustain teachers' persistence in STEM teaching. Therefore, teacher education programs and professional development programs should focus on starting with promoting enthusiasm and efficacy. This may be with allowing pre/in-service teachers to realize the value of STEM education.

Teacher education and professional development programs should model effective and best practices for STEM teaching and provide teachers enough experience teaching STEM before teaching in the classroom. Given the lack of collaboration mentioned in many studies, teachers should be encouraged to collaborate. The reasons underlying the factors that hinder teacher collaboration should also be investigated.

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SECTION II - STEM TEACHER EDUCATION

Chapter 3 - STEM Teaching and Learning Model in Egypt: Retrospect and Prospect

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Chapter Highlights

- This chapter describes the origin of a unique STEM focused model of high school curricular organization that is purpose-driven based on the Grand Challenges of Egypt.
- The Egyptian STEM schools were developed in collaboration with three U.S. technical partners; a field team comprised of former Ministry of Education officials; and the Ministry of Education and Technical Education. (MOETE).
- The results of the Model STEM schools have been students who have excelled at winning international competitions as never before as well as scholarships to attend premier U.S. and European colleges and universities. The success of this model has led USAID-Egypt to invest in a second follow-on $24.2 million project to develop and implement a new STEM teacher preparation program in five Egyptian universities that involve approximately 160 new courses.
- Further, the MOETE has used the integrated thematic curricular approach of the STEM high school model to introduce Education 2.0 reform efforts k-6 across all of the primary school in Egypt.

Introduction

The purpose of this chapter is to briefly describe the process by which nineteen public residential STEM High Schools (grades 10, 11 and 12) were established in Egypt that promise to revolutionize education in Egypt as well as provide a model for other countries around the world. These innovative Egyptian STEM high schools are the result of a decade of collaboration between the governments of Egypt and the United States Government as mediated through the *U.S. Agency for International Development* (USAID). The students from these STEM schools have won many international awards with many of them being admitted to and graduating from prestigious Egyptian, U.S. and European universities with full scholarships.

Furthermore, these STEM high schools have inspired a larger national reform effort in Egyptian basic education through their use of a transdisciplinary, project-based and inquiry-driven curriculum. The success of the STEM High School Model has resulted in a national commitment to expanding the number of these schools in Egypt that has paved the way for a second USAID project to introduce STEM teacher preparation in five Egyptian universities. To respond to the need for highly qualified STEM teachers to support these STEM high schools, USAID contracted the *21st Century Partnership for STEM Education* (21PSTEM) to implement the STEM Teacher Education and School Strengthening Activity (STESSA) project. STESSA has two goals:

1) to support the expansion of the network of STEM high schools across Egypt in collaboration with *the Ministry of Education and Technical Education* (MOETE), and
2) to develop five new integrated STEM teacher education programs at undergraduate level and two programs at the graduate level in collaboration with the Ministry of Higher Education and Scientific Research.

Challenges to Reforming Egyptian Education

Historically, there have been many structural barriers to improve the quality of the Egyptian pre-university education. Notable among these are the following as highlighted by Loveluck, (2012), Abouserie and Merlino (2014) and Pomeroy, Merlino and Morrison (2014).

A High Stakes/college Entrance Assessment System

Enrollment in public universities is based only on a single composite score of the high school exit exam known as the 'Thanaweya Amma.' This system creates an extremely high stakes testing environment that puts enormous pressure and stress on both students and their families.

A Focus on Rote Learning for Examinations

The traditional approach in the public schools is devoted to memorization and the use of textbooks. In turn, the national high school exams emphasize questions that involve detailed memorization and declarative knowledge. Because no other methods of assessment are used to test for other types of knowledge, such as analysis, synthesis, problem solving or evaluation, the curriculum is structured to emphasize rote memorization and declarative knowledge. The exam questions are closely aligned to the textbooks. As a result, there is an overreliance on the use of textbooks as the main source of information to the exclusion of other learning materials.

Private Tutoring

Because of the fact that the Thanaweya Amma is the sole determination of a young person's future educational pathway, and because these exams so closely follow the textbook, private tutoring is a big business. The poor quality of teaching and learning at school level has led to the emergence of a parallel, informal education system, where private tutoring is used to fill the educational gaps left by formal schooling (Egypt's Central Statistics and Mobilization Agency, 2020).

Lack of Highly Qualified Teachers

Successful implementation of any educational reform rests on committed, highly qualified teachers. For decades in Egypt, graduates of education programs were the main source of development for the teaching profession. Teachers were automatically promoted according to seniority, and they received little or no professional development during their career before the establishment of the Professional Academy for Teachers, ("PAT") in 2008. According to the National Strategic Plan of 2007 - 2012, teachers lacked many professional and effective teaching skills and a major reform was needed to enhance teacher efficiency and the use of modern teaching methodology.

Poorly Skilled Graduates

Despite the achievements made in providing access to primary and preparatory education, many students coming out of the education system are not equipped with the skills required by the business community to compete in the modern global economy.

Declining Students' Interest in Science and Math

According to the Egyptian Pre-University Education Strategic Plan (2007 – 2012), students' interest in science and mathematics was declining. "There was reluctance of preparatory stage graduates to join the Science track of the general secondary education, with only 10% of them, whereas the rest join technical secondary education or the literary section of the general certificate" (Egypt Ministry of Education (MoE), 2014, p.41). This aversion of students studying science and math is apparent also at the tertiary level. The Minster of Higher Education, Dr. Khaled Abdel-Ghaffar (El Yom el Sabea, Sep. 10th, 2020), announced that the numbers of student enrollment show that similar trends are observed and that the majority of Egyptian university students prefer to major in humanities (249,713 students) rather than sciences (160,415 students). This clearly demonstrates that most students steer away from the science and math specializations and fields despite their significance for the country's development. As Egyptian Nobel laureate Dr. Ahmed Zweil stated: "Human resources are just tremendous in Egypt, but we need the science base; we need the correct science base." He further added that: "Investing in science education and curiosity-driven research is investing in the future."

Welcome to the Dream: The Story of Establishing STEM Education School Model in Egypt

An Egyptian Visit to the United States

USAID has provided decades of educational assistance to Egypt in the form of projects aiming to increase access and improve quality of education at district and governorate levels.

Nonetheless, challenges remained in terms of bureaucracy, scale, and complexity of the Egyptian education system. A more radical change was needed, especially in the high schools.

Three key leaders led the way: Drs. Ahmad Gamal El-Din, Minister of Education (2011); Reda Abouserie, First Deputy to the Minister of Education for General Education (2005-2012); and Hala El-Serafy, the Egyptian Education Officer at USAID-Egypt with experience with the MoE in various education reform projects. These three people strongly believed that the time was ripe to change the rigid secondary education system in Egypt and introduce Egyptian students to a new teaching/learning model that emphasizes scientific research with different curriculum and assessments.

Accordingly, in 2010, Dr. Abouserie led a delegation to visit Thomas Jefferson High School for Science and Technology (TJHSST) in Fairfax, Virginia. U.S. News and World Report had ranked TJHSST highest among STEM school in the United States. In TJHSST, the delegation saw a potential model that can be introduced to inform education reform in Egypt. STEM education seemed to offer the possibility of a better way for math and science education through inquiry-based and project-based learning. During the summer of 2011, the MoE Minister, Dr. Gamal-Eldin held a series of meetings with prominent educational leaders and scientists to discuss strategies for educational reform, including a review of STEM schools in the U.S.

In response, USAID-Egypt, through Dr. Hala El-Serafy, sponsored a delegation of the MoE, headed by Drs. Gamal El-Din and Abouserie, to visit several STEM schools in Philadelphia, Pennsylvania and Virginia. Consequently, he issued a decree for the establishment of the Egyptian STEM high school's model. The first school was scheduled to begin in September 2011 as a residential school. At the time, however, there were no STEM curricula or alternative assessments, other than those used in the traditional system. Above all, there was no true sense of what a STEM curriculum suitable for Egypt should include or look like (Abouserie & Merlino, 2014).

USAID-Egypt Support for the Dream

In response to the MOETE request, USAID-Egypt provided the needed technical and professional support for STEM education in Egypt. Accordingly, it provided emergency U.S. technical assistance for one year to the Egyptian Ministry of Education. This emergency support was followed by a four-year $25 M award to a consortium of four U.S. organizations under the title, *Educational Consortium for the Advancement of Schools in Egypt (ECASE), later called Egypt's STEM School Project (ESSP).*

In September of 2011, the first Egyptian STEM high school, the Six-of-October STEM School for Boys, was established. Students were selected to enroll in this school based on their achievements in the middle school exit exams and readiness to study science and mathematics. As a result, 150 boys were chosen from all over Egypt to join the school. In September 2012, another STEM school was established for girls.

In January, 2012, the U.S. consultants arrived in Egypt to visit the new Six-of-October STEM school, which had opened four months prior. After leaders from U.S. technical partners made their way to the principal's office, in walked a beaming Dr. Reda Abouserie. With arms wide open, he smiled and said, "*Welcome to the Dream.*" The U.S. technical experts, led by the 21st Century Partnership for STEM Education (21PSTEM), began the work on the dream.

The first step was to develop a *Curriculum Framework* that would describe the principles of the curriculum and the process by which it would be developed. The cornerstone of the framework was the clear articulation of the purpose to the STEM school which be used to shape the curriculum. After a series of discussions between the U.S. team, the teachers and principal of the Six-of-October STEM school, and officials from the Ministry, they agreed that the core goal of the school should be to produce *"socially responsible leaders who are technically prepared to address the Grand Challenges of Egypt*."

The Curriculum Framework proposed a project-based, inquiry-based, integrated STEM curriculum based on the Grand Challenges together with a series of semester long Capstone projects. To break the dependence on textbooks, the STEM schools were provided with resource books and technology to support scientific research. The schools were exempted from the national high school exit exams, which were closely aligned to the textbooks in the mainstream schools. Instead, an *Assessment Framework* was adopted with multiple outcomes measures. A detailed outline for a four-week professional development institute (PDI) to prepare teachers for STEM schools was devised and implemented for all teachers.

Unique Features of STEM Public Schools in Egypt

Addressing Egypt's Grand Challenges

The Egyptian STEM schools are designed to develop socially responsible leaders to address the following Grand Challenges. They are considered the curriculum design pillars and include the following:

Table 1. Grand Challenges

1. Improving the use of alternative energies,
2. Recycling garbage and waste for economic and environmental purposes,
3. Dealing with urban congestion and its consequences,
4. Working to eradicate public health issues/disease,
5. Increasing the industrial and agricultural bases of Egypt,
6. Addressing and reducing pollution fouling of air, water and soil,
7. Improving uses of arid areas,
8. Managing and increasing the sources of clean water,
9. Dealing with population growth and its consequences,
10. Improving the scientific and technological environment for all, and
11. Reducing and adapting to the effect of climate change.

In addition to these curriculum design pillars, the STEM schools in Egypt are characterized by other unique features, explained in the following sections.

Engineering Design Process, Backward Design

The curriculum is designed according to the Backward Design Process that begins with identifying learning outcomes, and then developing formative and summative assessment to augment teaching/learning activities. It uses an integrated approach where students use their newly gained knowledge and skills in Science, Technology, Engineering and Mathematics disciplines to contribute to solving Egypt's Grand Challenges.

Student Centered Pedagogy

Teachers are trained to use modern methodologies including: active learning, project-based, inquiry-based and student-centered teaching and learning strategies to foster effective learning environment and student engagement. Since the curriculum is not textbook-based, students are encouraged and required to search for relevant information from various resources, which prepare them to become autonomous life-long learners. The pedagogy is also designed to support teachers foster their students' character building and soft skills. This is then reflected in their individual/group projects and effective presentation skills.

Multiple High Level Assessments

Assessments in STEM schools are not the traditional rote-learning exams where students are taught to be test-oriented and suffer from strain and stress of the one-shot exam at the end of the school year. Instead, formative and continuous assessments are given more weight than the traditional summative assessment. A focus on assessment for learning is in place as these schools adopt a digital application called PARLO (Proficiency-Based Assessment and Reassessment of learning outcomes). This system is accessible to students, teachers, principals, deputies and parents. Furthermore, it is a color-coded visual representation of students' performance, where green means the acceptable level of realizing the learning outcomes, Blue denotes achieving above standard, yellow means attaining some learning outcomes, but need help while Red signifies not realizing the learning outcomes.

Capstone projects weigh 60% of the final score for grades 10 and 11; whereas the other 40% are divided to reflect the students' participation and tests quizzes, practical exams and end of semester exams. In grade 12, a capstone project is carried out only during the first semester and is assigned 20% of the student total score. For each disciplinary course/ subject; students are given two exams: one for the Test of Concepts (ToC), and the other is the University Readiness Test (URT).

Science and Digital Fabrication Laboratories

To support conceptual understanding, all of the STEM schools have science laboratories as well as digital fabrication labs. The Fab Labs support the quality of STEM education, provide equipment to the schools, and offers training in supply maintenance and equipment use (USAID Egypt, 2020).

Continuous Teacher Professional Development

As asserted by Dufour & Eaker (1998: 205), “there is no way to create good schools without good teachers and that success in any aspect of school reform depends on highly skilled teachers working in schools.” Hence, the importance of ongoing professional activities that STEM teachers engage in to build their knowledge, skills and keep them motivated, and empowered to improve their teaching for the ultimate goal of increasing their students’ learning. Regardless of their specialization, STEM teachers are all highly trained by joint teams of Egyptian and US experts on the curriculum, assessment, the specific pedagogy of STEM schools, and capstone and on integration.

Specific training on specialized disciplines (STEM) are also offered periodically for a further deep dive into these subjects with a focus on learning outcomes, preparing lesson plans to be uploaded on the curriculum application. Practical, hands-on training on scientific experiments is also carried out on regular basis. Moreover, because English is the medium of instruction in the STEM schools, STEM teachers are constantly supported to enhance their English language proficiency to be able to conduct their classes effectively. This focus on ongoing teacher professional development reflects an important and a pivotal aspect of STEM philosophy.

Student Outcomes/ Achievements

Soon after the launch of the Six-of-October and Maadi STEM schools, it became evident to nearly all stakeholders who interacted with the students that there was a marked change in the students’ mindset and achievement as compared to their previous school experience. This was demonstrated in students’ rapid English language improvement, notable increase in their autonomy, less reliance on teachers, higher sense of commitment to the school community and collaboration, and overcoming stage fright while presenting their capstone projects and posters.

Furthermore, the 6 Oct and Maadi STEM students went on to win many international competitions, such as: International Science and Engineering Fair (ISEF), International Sustainable World Energy, Engineering and Environment project (I-SEEP), Science and Mathematics Olympiad and the Taiwan Science Fair. Most graduates of STEM schools go on to enroll in science colleges in Egypt. Many students are enrolled and granted full scholarships in reputable universities in both Egypt and abroad, such as: Stanford University, MIT, Harvard University in the U.S., Zweil University, The Nile University, and the American University in Cairo (AUC), to name just a few.

As a result of this success, the Egyptian government decided to expand the STEM Model schools nationwide, one school in each of its 27 governorates. This expansion has led to a need to provide the STEM schools and other Egyptian schools with a steady stream of highly-qualified STEM teachers and leaders.

The STEM Teacher Preparation and School Strengthening Activity (STESSA)

To address the new challenges of expanding the Egyptian STEM school model, a five-year, $24.2 M contract from USAID-Egypt was awarded to the *21st Century Partnership for STEM Education (21PSTEM*) on April 26, 2018 to implement a follow-on five years project called the *STEM Teacher Education and School Strengthening Activity or STESSA*. The Egyptian partners of this STESSA project include the Ministry of Higher Education (MOHE); five universities: Ain Shams, Zagazig, Mansoura, Assuit and Minia; the Ministry of Education and Technical Education (MOETE); the *Professional Academy of Teachers* (PAT), and the *National Authority for Quality Assurance and Accreditation in Education* (NAQAAE). From the U.S. side, partners include five U.S. universities: Arcadia California State - Fresno, California Polytechnic State (Cal Poly), Drexel, and Temple, along with World Education and COSI.

The STESSA project has three overarching goals: to help expand and institutionalize the STEM schools; to develop and sustain a high-quality STEM teacher education program, and to build strong, harmonious relationships between STEM teacher education programs and the STEM schools so as to work as a single STEM education system.

The STESSA higher education component aims to develop a specialized cadre of instructors and administrators to teach at and lead STEM high schools nationwide. This Component also aims at fostering and spreading the STEM culture and philosophy of integration. It comprises two STEM programs. The first one aims at establishing two post-graduate diplomas at 5 accredited Egyptian universities; the second one is to launch a 4-year STEM undergraduate teaching degree program. Both are briefly described below.

The selection criterion for Egyptian university participation was set by the Education Sector Committee (ESC) of the Supreme Council of Universities. Two key requirements were that a university's education program had to be accredited and had to have access to a STEM school in their respective governorates.

Two Post-Graduate Diploma Programs

Two one-year Diplomas were established*: STEM Teachers' Professional Diploma*, *and STEM Leaders' Professional Diploma*. These new one year post-graduate Diploma programs have been developed and implemented in all five of the aforementioned Egyptian universities. They all have a common set of Bylaws approved by the Egyptian *Education Sector Committee* (ESC) as well as the Egyptian *Supreme Council of Universities* (SCU). The diploma curriculum, pedagogy and assessment echoes the philosophy and the design of the Model STEM high schools.

High-tech smart teaching rooms were procured for the Faculties of Education and Science for the five participating Egyptian universities. These teaching rooms are designed to foster active learning environment that would maximize students' learning and potential, as well as improve their autonomy. Professional Learning Communities (PLCs) were established for the first time at each of the five Egyptian universities with U.S. counterparts in five American universities. The PLCs bring together, and for the first time, professionals from each discipline in the 5 Egyptian universities in the 3 faculties involved in both designing and teaching the STEM programs -- Faculty of Education, Faculty of Science and Faculty of Engineering.

4-Year Undergraduate STEM Teacher Preparation Program

STESSA has successfully obtained approval from the ESC and SCU for a new integrated Four-Year Undergraduate STEM Teacher Preparation Program comprising 141 new courses. The curriculum mirrors the STEM schools' innovative and unique philosophy in the way it is organized. There are several unique features of the STESSA STEM Teacher Preparation Program:

STEM High School Alignment

The higher education teacher preparation curriculum is aligned with the philosophy and principles of the STEM schools in terms of being based on Egyptian Grand Challenges, the Engineering design process (Backward Design), assessment techniques, active learning, student-centered teaching and learning strategies, inquiry-based and project-based learning (Capstone projects), integration of information and communication technology.

The Six Plus Ten Model and Early Practicum

The teacher preparation curriculum mirrors the STEM schools' innovative and unique philosophy in the way it is organized. The high education model incorporates *six* transdisciplinary courses for all students in the five programs plus *ten* disciplinary courses for each of the five specializations: Physics, Chemistry, Biology, Earth Sciences and Mathematics. In addition, it offers educational courses, practicum, Capstone projects and university prerequisites, such as: Human Rights, Arabic language, English Language and Ethics.

These courses are integrated and aligned with Egypt's Grand Challenges to prepare student teachers to teach the curriculum in the Egyptian STEM schools. The practicum starts from the first year in the undergraduate program to allow STEM prospective teachers to get used to the school, and to give them a chance to observe and be fully acquainted with the school environment. Different practicum formats are employed each semester such as micro-teaching, Learning Assistantships, and summer camps.

Collaborative Teaching Using Smart Teaching Rooms

The six transdisciplinary courses are designed to be collaboratively taught by multidisciplinary teams of professors to reinforce the integrated features of the STEM model, as well as to embody the concept of the unity of knowledge. To facilitate collaborate teaching and the use of student centered activities, high-tech smart teaching rooms have been procured for the Faculties of Education and Science for the five participating Egyptian universities to maximize students' learning and potential, and improve their autonomy.

Faculty Professional Learning Communities (PLCs)

Similar to the Diploma programs, PLCs are established at each of the five Egyptian universities with U.S. counterparts in five American universities. Likewise, the PLCs bring together professionals from each discipline in the 5 Egyptian universities in the 3 faculties involved in both designing and teaching the STEM programs -- Faculty of Education, Faculty of Science and Faculty of Engineering.

English as a Medium of Instruction (EMI)

English as a Medium Instruction (EMI) is a key area of work under this STESSA project. Promoting English as the language of instruction is a necessity and strategic choice because English has become the international language of choice in the STEM context. Hence, two English courses were designed for each of the two STEM diploma programs. These courses aim at developing STEM teachers' and leaders' use of English as a Medium of Instruction in the STEM schools. In parallel, STESSA's English team designed and conducted an 8-week "English for Teaching Purposes" course to support professors' language skills in order to teach their courses fully in English.

At the undergraduate level, the 4UG program Bylaws stipulated eight ESP (English for Specific Purposes) courses across the 4 undergraduate years instead of the two courses that are currently taught at the Faculty of Education. These courses are being designed to reflect the language functions in teaching STEM disciplines, such as: asking inquiry and probing questions, labeling, describing and using graphs, and using argumentation, following the

Stanford model. Furthermore, professors will be trained on using EMI in teaching their courses just like those of the diploma programs.

National Standard Setting

STESSA was able to reach an agreement with NAQAAE to set standards for both the postgraduate/undergraduate programs and STEM schools accreditation. Currently, these standards are being validated by Egyptian stakeholders as well as U.S. consultants.

STEM School Sustainability

To institutionalize the STEM model in Egypt, the STESSA project is working closely with the MOETE central STEM unit and PAT to strengthen and expand the pipeline of trained, competent personnel in different STEM areas. The following are the larger efforts that were carried out and/or being implemented at STEM Schools through the help of STESSA's field office and home office.

Establishing Local STEM Units

Following the establishment of STEM Local Units in 15 governorates, STEM local supervisors from these governorates were trained to assume their roles as effective members in these local units. Their role is to oversee and support STEM teachers in their respective schools. Training is comprised of an overview of STEM education concepts and philosophy and familiarizing them with the Classroom Observation Scale (COS) so as to be better prepared to observe, coach, mentor and provide constructive feedback to their STEM teachers.

Training All STEM Teachers and Principals

STEM teachers are constantly trained through providing them with an overview of STEM education concepts and philosophy, Understanding by Design (UbD), lesson planning, curriculum, use of the Classroom Observation Scale (COS), active learning strategies and practical activities. School principals and deputies are offered training for the purpose of reflecting on achievements and challenges, their roles and responsibilities in their school

Improvement Plan, and in developing their understanding of an effective Professional Learning Community (PLC). Potential school leaders were also familiarized with the STEM curriculum, assessment system, capstone projects and Fab Labs.

Furthermore, they were introduced to good leadership practices and continuous professional development through PLCs. Fab Lab managers in all schools were trained on Fab Lab management, maintenance of equipment and troubleshooting. The training also aimed at assisting Fab lab managers to develop their abilities to deal with complex tasks through co-learning, researching and collaborating to find solutions for themselves.

Capacity Building for Assessment

STESSA's experts are working closely with MOETE and the counselors of Math, Science and English to enhance the skills of item writers. Training was conducted in writing items for the STEM University Readiness Test (URT) and item bank development. Since Capstone projects are a major feature of the STEM school, continuous efforts at building the capacities of capstone challenge design and journal item writing teams are needed. Collaborative efforts are taking place between the U.S .experts and the STEM Unit capstone coordinator and the capstone challenge team. These efforts materialized in a database of over 100 challenge ideas to meet the needs of the schools, and in reviewing and improving the content and the English writing of these items by trained English specialists nominated by the STEM unit.

Reviewing and Implementing Personal and Safety Plan

STESSA identified exemplary personal and environmental safety procedures and guidelines in the U.S. and began a process to provide more specialized technical assistance to STEM counterparts to build in-house capacities to help them monitor personal and environmental safety at all levels.

ESOL Training

STESSA's English team developed and conducted an 8-week ESOL Blended Training program to improve the use of EMI in the STEM schools. The program targeted all STEM subject teachers as well as the Academic Deputies in 15 schools, and aimed to promote participants' academic English skills and language proficiency to carry out their classes in English. An e-STEM platform was designed as an extra-curricular activity to assist the STEM students and teachers in improving their English language use. STESSA held several workshops to support the STEM school staff in reinforcing the use of the platform inside and outside of the classroom.

To systematize the activities and expand knowledge about successful examples, STESSA's U.S. experts developed a manual including best practices and included a landscape scan for online tools that could be effective in the STEM context. An Outreach Program (e-STEM for Preparatory Schools) was designed as an extra-curricular activity to raise middle school students' awareness of the STEM subjects as well as promote their English language proficiency. This program is implemented in all Egyptian middle schools nationwide. Currently, a manual is being developed to support the teachers in effectively applying the program with their students.

Discussion

The Egypt STEM high school model has been growing and evolving over a ten year period. It is having a significant impact on the whole general education reform effort currently being carried out in Egypt. STESSA's contribution to the national reform environment extends beyond STEM schools and being reflected in many facets of the Egyptian Education system.

The salient features of the STEM education (integration, inquiry-based, project-based, active/student-centered learning) have been supported by the Minister of Education Dr. Tarek Shawky through the adoption of the philosophy of integration in the new "Education 2.0" curriculum that is currently being implemented in grades k-6 in all schools. Dr. Shawky (2019) summarized the efforts to transform Egyptian education that started in 2018 with KG1, KG2 and Primary 1, and that would continue year after year till 2030:

> *We are transforming the way in which students learn to prepare Egypt's youth to succeed in a future world that we cannot entirely imagine…Education at a young age also needs to be multidisciplinary to broaden students' horizon, integrating the essential soft skills and competencies such as communication and critical thinking into the school curriculum.* (p. i)

Conclusion

While more work remains ahead the path is clear. Guided by national strategic priorities, buy-in from the different stakeholders in Egypt, and early signs of success, the Egyptian STEM Teaching and Learning Model represents nothing less than a breakthrough in education in general and STEM education in particular to equip a younger generation with the knowledge, skills and moral disposition to address the grand challenges faced by Egypt, and indeed the rest of the world.

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Chapter 4 - STEM Teachers' Job Satisfaction: From the Lens of Job Demands-Resources

Ke Wang, Yu Xiao

Chapter Highlights

- This study confirmed the validity of the theory of job-demands-resources explaining STEM teachers' job satisfaction.
- The study shows job resources had a significantly positive effect on STEM teachers' job satisfaction and job demands negatively affected STEM teachers' job satisfaction
- The study supports that the factor of wage is another significant factor for STEM teachers' job satisfaction and high-school teachers perceived higher job satisfaction than middle-school teachers.
- This study provides school administrators and policymakers with effective strategies to alleviate the shortage of certified STEM teachers.

Introduction

International STEM education at schools in the U.S. has obtained dramatically increased interest over the past decade (e.g., Jones, et al., 2016) because the nation has been facing a shortage of certified teachers in STEM (e.g., Hutchison, 2012). National authorities including the U.S. Department of Education and the National Science Foundation have made great efforts to address this serious issue. The White House (2016) stated that in a continued effort to support pipelines bringing outstanding teachers into STEM classrooms, ED plans to invest $125 million in the *Teacher and Principals Pathways* program to fund teacher-preparation programs and nonprofit organizations that collaborate with school districts to create or extend high-quality teacher career pathways, especially into high-demand schools and high-demand disciplines like STEM. In a *Presidential Memorandum* signed by President Trump, the Department of Education was directed to make STEM and computer science education a top priority (The White House, 2018).

The common solution to the shortage of STEM teachers includes two main aspects: increasing the recruitment of STEM teachers and reducing teacher departures. In this study, we focus on the latter to explore: how to moderate the rate of teacher turnover? As we know, one most effective way to lower the rate of teacher turnover is to find the real reasons for teachers leaving the profession. Meanwhile, teachers' job satisfaction is a primary indicator of teacher attrition. In other words, teachers who have higher satisfaction could stay in the profession for a longer period; teachers with lower satisfaction have higher possibilities to leave their jobs. Albeit extensive studies have explored potential factors and their correlations to teachers' job satisfaction (TJS) (e.g., Karisan, Macalalag, & Johnson, 2019; Minken et al., 2021; Skaalvik & Skaalvik, 2011, 2018), few of them explored the factors for STEM TJS from the lens of the job demands-resources (JD-R) theory (Bakker & Demerouti, 2014, 2017).

From the standpoint of job demands, STEM teachers face several challenges: a) understand interdisciplinary knowledge like mathematics, science, engineering, and technology; b) master STEM instructional strategies; c) improve students' interest in STEM. As the Committee on STEM Education (2018) claimed, "Modern STEM education imparts not only skills such as critical thinking, problem-solving, higher-order thinking, design, and inference, but also behavioral competencies such as perseverance, adaptability, cooperation, organization, and responsibility" (p. 1). Where the job resource is concerned, with the higher requirements of STEM teachers, job resources (e.g., support from school, professional development for STEM instruction, etc.) should be provided for STEM teachers to support their teaching. As long as adequate job resources are provided for STEM teachers, they would have more confidence and less pressure in teaching. Furthermore, teachers' job satisfaction could not be easily reduced by the higher job demands and their leaving intention could be lower. In current study, we will explore how job demands and job resources predicted STEM TJS through employing the JD-R theory and investigate the relationships between TJS and other endogenous factors of STEM teachers.

Literature Review

Job Satisfaction

Many studies have identified that TJS is a significant contributor affecting teacher retention, and teacher motivation (Ingersoll, 2003; Skaalvik & Skaalvik, 2011). The research on TJS is to a teacher-group based on general job satisfaction research. Its various definitions have expanded different research paths for TJS research. According to Zhu (2013), the first formal definition of job satisfaction can be traced back to Fisher and Hanna (1931), who described job satisfaction as a non-regulatory mood tendency based on a large number of case studies. Then, Hoppock (1935) defined the concept of job satisfaction as any combination of psychological, physiological, and environmental circumstances which lead a person to express satisfaction with his/her job. In Hoppock's (1935) view, job satisfaction is a single concept of the overall mental state, rather than expressing it in several isolated levels. Considerable amounts of scholars have given different definitions of job satisfaction. For instance, Locke (1969) regards job satisfaction as the psychological satisfaction and fulfillment that an individual can get from doing his or her job. Porter and Steer (1973) clarified that job satisfaction is determined by the gap between what individuals expect to get and what they actually get in their jobs: the smaller the gap is, the greater job satisfaction one can get. Roberts et al. (1971) considered that job satisfaction is an emotional expression based on whether one's needs at different levels of work are satisfied. Correspondingly, there are different levels and structures of needs formed by job satisfaction.

Teachers' Job Satisfaction

When focusing on teaching as a profession specifically, Dinham and Scott (2000) identified job satisfaction as an influential factor of teachers' professional development, and such research has become the forefront in the field of teacher psychology and educational development. They classified the sources of TJS into three categories: (a) teachers' intrinsic rewards, (b) school-based factors, and (c) out-of-school factors. Simmons (1970) divided the structural factors affecting teachers' job satisfaction into content and context factors. Content factors are associated with the teaching process (e.g., teaching performance, the nature of the work, recognition), whereas context factors involve the condition of the job (e.g., interpersonal relationships, school policies, salary, etc.). Content factors are corresponding to the top needs of Maslow's hierarchy (e.g., self-esteem and self-actualization). Meanwhile, context factors cannot generate TJS, they can only reduce teachers' job dissatisfaction at the lower-level needs such as physiological and safety demands.

Based on the theories mentioned above, extant literature examining the effects of factors on TJS was searched and analyzed. For instance, In Skaalvik and Skaalvik's (2018) study of 760 Norwegian teachers in grades 1-10, the results showed that support from colleagues is a critical determinant of teacher well-being. Not only the supports from colleagues, but support from administrators has also long been correlated with TJS (e.g., Brown & Wynn, 2009; Griffith, 2004; Petzko, 2004). Another school-based context factor, distributed leadership, is positively correlated with TJS (Liu et al., 2021; Sun & Xia, 2018).

On the other hand, many studies have shown that students' misbehavior has substantial direct effects on TJS (e.g., Camp, 1987; Landers et al., 2008). In addition, students' backgrounds can also make great contributions to TJS. McCarthy et al. (2012) revealed students' background is related to TJS as teachers in culturally and racially diverse classrooms find it more demanding in respect of classroom resources. In this study, the conception of job satisfaction was defined as a composite measurement including three aspects: 1) teacher-perceived satisfaction level of being a teacher in this school, 2) the satisfaction level of all teachers as a group with their school, and 3) how much the teacher likes the management style of this school (NCES, 2021).

The Job Demands-Resources Model

Various factors that lead to burnout have been identified by scholars in their studies, and each occupation happens to have specified factors that lead to burnout. For instance, patients' demand is a significant burnout predictor (Wang et al., 2015); for reporters, workload and news autonomy are critical in predicting burnout (Liu & Lo, 2017); Friedman (2006) accentuated the pivotal role of teacher-student relations in teachers' burnout. To address the impact of different factors on burnout in each occupation, Demerouti et al. (2001) indicated that all these factors can be grouped into two categories: job demands and resources, and thus the JD-R model was established using the initials of the two categories. Job demands factors (e.g., workload, interpersonal demands, role ambiguity, etc.) are physically, organizationally, or socially related and require continuous physical or psychological effort. Job resource factors (e.g., organizational support, job control, career opportunities, etc.) can reduce the physical and psychological costs of work demands, achieve work goals, and promote individual learning, development, and growth. Burnout occurs when job demands are too high, specific manifestations include excessive work pressure and work-family conflicts. In addition, insufficient job resources such as inadequate organizational support and inadequate opportunities for individual decision-making autonomy can also lead to burnout. The model has been applied in occupational studies including teachers, doctors, police officers all over the world (van Beek et al., 2014).

The JD-R model combines both job demands and job resources factors into a unified framework, and addresses both positive and negative impacts of these factors on job satisfaction together so as to a balanced, comprehensive, and stereoscopic analysis framework. Specifically, we believe that the JD-R Model provides an appropriate theoretical framework for us to analyze teachers' job satisfaction from the perspective of various groups of people teachers encounter from top to bottom in schools, including school leaders, teacher colleagues, and their students.

Extant studies have consistently proved the hypothesis of the JD-R model that there exists a significant correlation between job demands/resources and emotional perceptions like job satisfaction. For instance, after conducting the Confirmatory Factor Analysis and SEM analysis to the data from 760 Norwegian teachers teaching grade 1-10, Skaalvik and Skaalvik (2018) found that job demands have negative impacts on TJS and increased teachers' leaving intention. Yeh (2014) conducted a stepwise regression modeling analysis on 1,666 employees' job satisfaction in three East Asian countries/regions: Japan, Taiwan, and South Korea. The result indicated that job resources including earnings, job content, and workplace relationships increased job satisfaction. Tims et al. (2013) demonstrated a similar view that job satisfaction tends to increase when job resources increase by investigating 288 employees working at a Dutch chemical plant.

The Conceptual Framework

To examine and refine the JD-R model in education, Bakker et al. (2005) collected data on 1,012 employees from a large educational institution to validate the buffering effect of job demands factors including social support, quality of the relationship with the supervisor, and autonomy on job demands to job burnout. Their selection of job resources factors sheds light on this research. It is extremely crucial for teacher colleagues to support each other. The solidarity of teachers will fundamentally affect the organization because they embody a sense of responsibility for all activities (Baluyos et al., 2019). Steele et al. (2015) found that financial resources did not significantly impact teachers' leaving intention; however, the relationship with their peers is a strong predictor of willingness to leave. In addition, teachers' job satisfaction can be lowered when they do not receive support from administrators and colleagues as they may find they are unappreciated (Prilleltensky et al., 2016).

Support from administrators is another vital source of teachers' job resources. Baker (2007) indicated that higher administrative support can lead to greater teachers' job satisfaction and she further ascertained that the degree of teachers' perceived administrative support contributes to the teachers' decision to their job retention, after an investigation was conducted on 87 early career teachers and their principals from five regions in North Texas.

The demonstration of distributed leadership is directly related to teacher autonomy (Bicer, 2021, Trammell, 2016; Vu et al., 2019). As a result, the distributed leadership model has received a broad range of attention, it was the most frequently researched of all educational leadership models studied between 1980 and 2014 (Gümüş et al., 2018). After analyzing the 2013 TALIS data, Liu et al. (2021) found that distributed leadership is positively and directly correlated to TJS.

Scatterbrained, classroom disruptions, and discipline problems are several typical students' misbehaviors that have been proven to negatively affect teachers' job satisfaction, according to several studies (e.g., Aloe et al., 2014; Sendogdu& Koyuncuoglu, 2022). One possible reason is that student misbehavior can result in teachers feeling rejected and discourage them from developing intimate bonds with their students (Admiraal et al., 2019; Keskin et al., 2020; Nurmi & Kiuru, 2015; Uhomoibhi & Ross, 2018).

According to the above introduction, we build a conceptual model for STEM TJS (see Figure 1). Therefore, in this study, we will examine the contributions of the factors to TJS by employing Confirmatory Factor Analysis and Structural Equation Modeling. Based on the literature (Bakker & Demerouti, 2017), the JD-R model can well explain burnout and work engagement. We will examine their respective contributions to STEM TJS. Finally, we will examine the contributions from the five popular factors to STEM TJS. To be specific, three research questions will be addressed in the following: a) How do these factors affect STEM TJS in the conceptualized model? Which factor is more important? b) In the conceptual STEM TJS model, do STEM female teachers and male teachers vary in TJS? Do STEM teachers in different grade levels have different TJS? c) In the conceptualized STEM TJS model, do the three variables of working time per week, work experience, and hourly wage have a significant impact on STEM TJS?

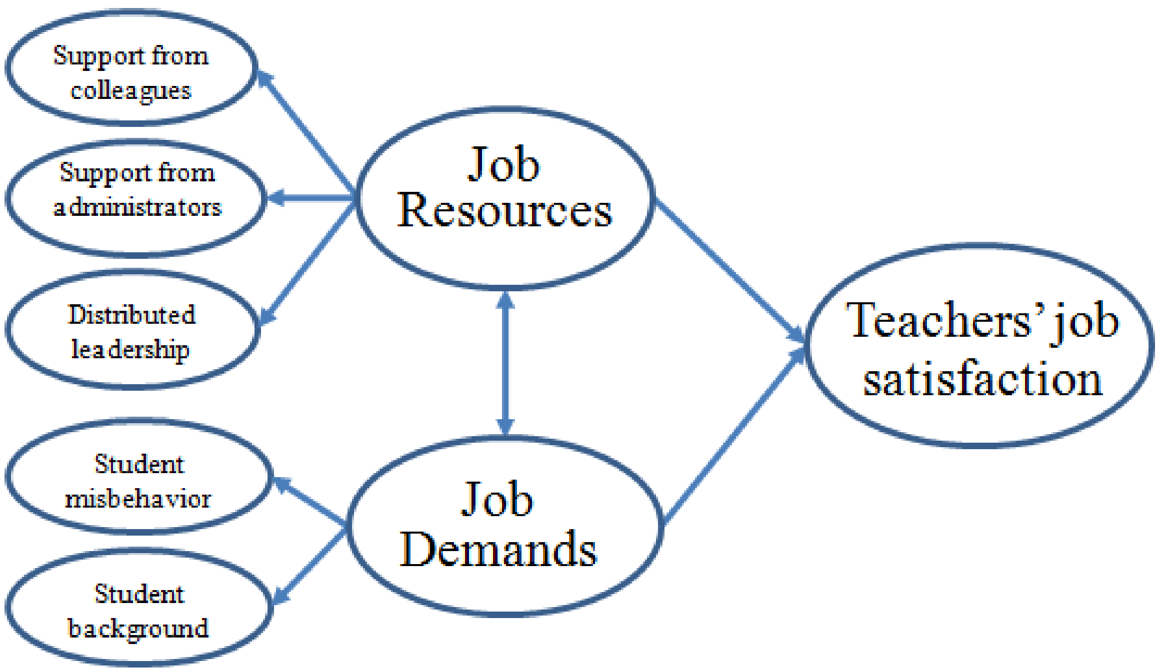

Figure 1. The Conceptual Framework for STEM Teachers' Job Satisfactions

Method

Data Source and Samples

The Schools and Staffing Survey (SASS) is a comprehensive study of public and private school districts, schools, principals, and teachers. Between 1987 and 2011, the National Center for Education Statistics (NCES) launched seven SASS studies in the U.S. Its purpose was to provide the descriptive data necessary to gain a thorough understanding of elementary and secondary education in the U.S. (NCES, 2021). SASS surveyed teachers' and principals' data including teacher demand, student, teacher, principal, and school characteristics. This study only utilizes the data from the Teacher Questionnaire-School and Staffing Survey 2011-12 School Year. The Teacher Questionnaire 2011-12 collects American secondary public-school teachers. This data is one part of the national restricted dataset, SASS 2011-12. Therefore, the data is one-level rather than two-level. All items for the variables in this study are from this survey. The data is based on teachers' perspectives. To select our sample, this study focuses on full-time STEM teachers. Therefore, we used the three questions from the Teacher Questionnaire to define STEM teachers and select STEM teachers: No 1. how do you classify your position at this school, that is, the activity at which you spend most of your time during this school year?---regular full-time teacher (in any of grades Kindergarten-12 or comparable ungraded levels); No. 16 this school year, what is your main teaching assignment field at this school? ---Mathematics, Computer Science, and Natural Science; No. 22 During your most recent full week of teaching, approximately how many hours did you spend teaching each of the following subjects at this school?---Arithmetic or mathematics, Science (more than 2 hours). Finally, the final sample consists of 7,905 STEM teachers without missing data.

Variable and Measures

According to the main topic of the teacher questionnaire, we created all latent variables by employing Confirmatory Factor Analysis. The latent variables include teachers' job satisfaction, support from colleagues, support from administrators, distributed leadership, student misbehavior, and student background (see Table 1). For example, the variable of teachers' job satisfaction is created based on three items from the teacher questionnaire based on our definition of job satisfaction: "I am generally satisfied with being a teacher at this school"; "the teachers at this school like being here"; and "I would describe us as a satisfied group". For another example, the variable of support from colleagues is created based on three items: "Rules for student behavior are consistently enforced by teachers in this school, even for students who are not in their classes"; "Most of my colleagues share my beliefs and values about what the central mission of the school should be"; "There is a great deal of cooperative effort among the staff members". However, the two variables of job resources and job demand in the conceptual framework were created by using second-order Confirmatory Factor Analysis.

According to the theory of job-demand-resources and our conceptual framework, the variable of job resources was created by the three latent variables: support from colleagues, support from administrators, and distributed leadership, and the variable of job demand was created based on two latent variables: student misbehaviors and student background. To assess the model fit, we used well-established indexes, RMSEA, CFI, and WRMR. For the CFI and TLI indices, values greater than .95 indicate a good fit of the data (Hu & Bentler, 2009). For well-specified models, an RMSEA of .06 or less reflects a good fit (Hu & Bentler, 2009). A WRMR less than .900 reflects a good fit (DiStefano, Liu, Jiang & Shi, 2018). In addition, a Cronbach's alpha of more than .700 is typically considered acceptable (Bland & Altman, 1997). All the indexes were used to examine and evaluate the models and creation of all latent variables in this study. All the indexes of the first-order Confirmatory Factor Analysis are shown in Table 1 (see appendix). The values of the indexes show that the creations of all variables are acceptable.

For example, the variable of teachers' job satisfaction was created based on three items: T0451, T0466, and T0467. Cronbach's alpha was .842. This means that the internal consistency of the three items is good. Meanwhile, the indexes of RMSEA, CFI, and WRMR (RMSEA = 0, CFI = 1, WRMR = .002) show the model of the creation of teachers' job satisfaction has a good fit. Furthermore, we created other variables, like gender, experience, work time, wage, and grade based on original items (see Table 1). We can get the variables of gender, experience, and work time directly from the questionnaire. The variable of wage was created based on the work time and annual income. With the assumption that teachers work 40 weeks in an academic year, we created the variable wage by dividing the total income from school by the multiplication of 40 weeks and teachers' total work time (i.e., hourly wage = the sum income ÷ (40 weeks × work time). In addition, we recode the variable of grade to be dichotomous: middle school = 0 (n = 3,197) and high school = 1 (n = 4,708).

Table 1. Items in the All Variables and Model Fit Indexes

Variable	Code	Problem	Loading
Teachers' job satisfaction	RMSEA=0, CFI=1, WRMR= .002, α = .842		
(To what extent do you agree or disagree with each of the following statements?)	T0451	I am generally satisfied with being a teacher at this school	.806
	T0466	The teachers at this school like being here; I would describe us as a satisfied group	.855
	T0467	I like the way things are run at this school	.882
Job resources			
Support from Colleagues		RMSEA=0, CFI=1, WRMR= .003, α = .746	
	T0442	Rules for student behavior are consistently enforced by teachers in this school, even for students who are not in their classes	.811
	T0443	Most of my colleagues share my beliefs and values about what the central mission of the school should be	.774
	T0445	There is a great deal of cooperative effort among the staff members	.730
Support from Administrators		RMSEA=0, CFI=1, WRMR= .002, α = .822	
	T0435	The school administration's behavior toward the staff is supportive and encouraging	.880
	T0441	My principal enforces school rules for student conduct and backs me up when I need it	.822
	T0444	The principal knows what kind of school he or she wants and has communicated it to the staff	.817
Distributed Leadership		RMSEA=0.02, CFI=.999, WRMR= .468, α= .733	
How much actual influence do you think teachers have over school policy at this school in each of the following areas?	T0423	Evaluating teachers	.684
	T0424	Hiring new full-time teachers	.699
	T0425	Setting discipline policy	.724
	T0426	Deciding how the school budget will be spent	.702
Job Demand			
Student misbehavior		RMSEA=0, CFI=1, WRMR= .002, α = .837	
To what extent is each of the following a problem in this school?	T0455	Student tardiness	.879
	T0456	Student absenteeism	.854
	T0457	Student class cutting	.825
Student background		RMSEA=0, CFI=1, WRMR= .002, α = .824	
To what extent is each of the following a problem in this school?	T0460	Student apathy	.770
	T0461	Lack of parental involvement	.853
	T0463	Students come to school unprepared to learn	.877
Gender	T0525	Are you female or male?	
Experience	T0040	In what school year did you first begin teaching, either full-time or part-time, at the elementary or secondary level?	
	T0534	What is your year of birth?	
Working hours	T0392	Including hours spent during the school day, before, and after school, and on the weekends, how many hours do you spend on all teaching and other school-related activities during a typical full week at this school?	
Hourly wage Calculate the sum of the income from school or related school work. Then, divide the sum by the multiplication of 40 weeks total work time. Hourly wage=the sum ÷ (40 weeks ×work time	T0508	During the current school year, what is your base teaching salary for the entire school year?	
	T0500	During the summer of 2011, did you have any earnings from teaching summer school in this or any other school?	
	T0509	During the current school year, do you, or will you, earn any additional compensation from this school system for extracurricular or additional activities such as coaching, student activity sponsorship, mentoring teachers, or teaching evening classes?	
	T0511	During the current school year, do you, or will you, earn any additional compensation from this school system based on your students' performance (e.g., through a merit pay or pay-for-performance agreement)?	
Grade stage*		Middle school and High school	
Do you currently teach students in any of these grades at this school	T0071-T0083	Middle school: 5-8 High school: 9-12	

**Note*: We re-coded the variable of grade stage into two categories, middle school (i.e. grade 5-8) and high school (i.e., grade 9-12).

Data Analysis

The analysis started by testing a collection of measurement models utilizing Confirmatory Factor Analyses. We employed the Mplus 7.4 program in this study. We defined a second-order job resource variable indicated by *support from colleagues*, *support from administrators*, and *distributed leadership*.

Also, we defined a second-order job demand variable indicated by *student misbehavior* and *student background*. Then, we tested a conceptual model for STEM TJS including two latent variables of job resources and job demands to answer the first research question. Finally, we further explored the different SEM models about the relationships between the three latent variables and the five variables (*hourly wage, work time, experience, gender*, and *grade level*) to address the second and third research questions.

Results

Zero-order correlations between the created latent variables and five original or combined variables as well as statistical means and standard deviations are shown in Table 2. The two variables of support from colleagues and support from administrators have strong positive relationships with TJS. Distributed leadership has a modest positive significant relationship with TJS. However, the two variables of student background and student misbehavior have modest negative significant relationships with TJS.

These two correlation findings confirm the three factors of support from colleagues, support from administrators, and distributed leadership could be job resources, and two factors of student background and student misbehavior could be job demands. In addition, teachers' hourly wage and experience are significantly and positively related to TJS. Surprisingly, the factor of total working time per week is significantly and negatively related to TJS.

First, we tested our framework for STEM TJS including job resources, job demands, and job satisfaction. The model results show a decent fit to the data (RMSEA = .058, CFI = .989, TLI = .977, SRMR = .018). This finding confirms that our conceptual framework is effective to explain STEM teachers' job satisfaction.

Table 2. Correlation, Mean, and Standardized Deviation

	TJS	SupC	SupA	Dis	SB1	SB2	W	T	Exp	G	MF
TJS	1.000										
SupC	.632	1.000									
SupA	.688	.647	1.000								
Dis	.396	.373	.384	1.000							
Sb1	-.362	-.335	-.283	-.168	1.000						
Sb2	-.413	-.344	-.288	-.238	.579	1.000					
W	.044	-.001	-.030	-.027	-.045	-.090	1.000				
T	-.034	-.037	-.027	.005	.036	.021	-.501	1.000			
Exp	.033	.010	-.016	-.072	-.093	-.064	.436	-.101	1.000		
G	-.027	-.119	-.030	-.006	.277	.082	.022	.028	.012	1.000	
MF	.015	-.010	.026	.071	.053	.024	.088	.004	.043	.166	1.000
Mean	-.019	-.007	-.042	.013	.004	-.017	28.442	52.920	12.760	.600	.39
SD	.697	.652	.727	.567	.782	.658	10.074	8.805	9.465	.491	.488

Note. TJS=Teachers' job satisfaction, SupC=Support from colleagues, SupA=Support from administrators, Dis=Distributed leadership, SB1=Student misbehaviors, SB2=student background, Wage=hourly wage, Time=Total working time per week, Exp=Experience, Grade=Grade level. Correlations < .030 are significant at $p< .05$ level. Correlations > .030 are significant at $p < .01$ level.

In addition, Figure 2 shows a strong positive relationship between job resources and TJS (beta = .759). There is a moderate negative relationship between job demand and job satisfaction (beta = -.128). The two findings further confirm that the two different factors of job resources and job demands can separately contribute to STEM TJS. There is a strong negative relationship between job resources and job demands (beta = -.502). This strong negative relationship between job resources and job demands implies a solution to solve the negative effect of job demands on TJS by improving the effect of job resources.

In sum, the job resources and job demands explained 69.1% of the variance in STEM TJS. These results reveal that the factor of job resources in this study strongly predicts higher levels of job satisfaction, whereas the factor of job demands predicts lower levels of job satisfaction. This finding is different from that in Skaalvik and Skaalvik (2018). Our findings show that the factor of job resources could be a significant factor for STEM TJS. Similarly, our findings confirm previous study about the JD-R model (Skaalvik & Skaalvik, 2018). The two factors are key contributors to TJS.

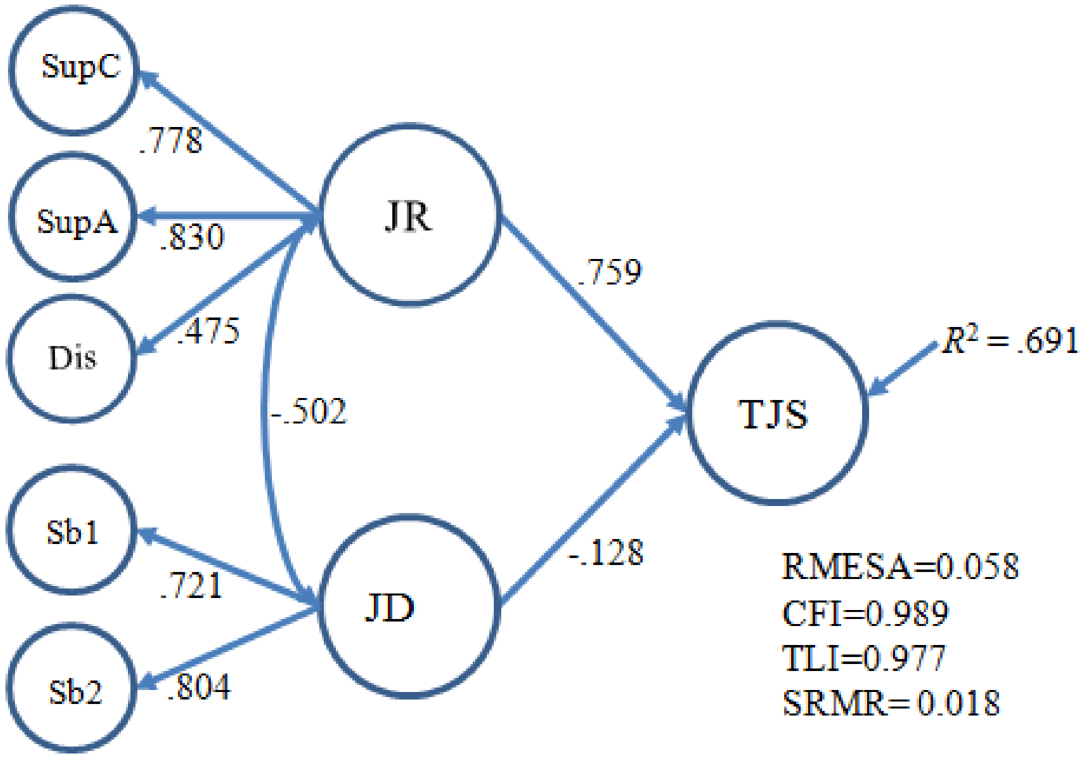

Figure 2. The First Model of STEM Teachers' Job Satisfaction

Note. MF = Gender, GL = Grade levels, T = Total working time per week, W = hourly wage, Exp=Experience. TJS = Teachers' job satisfaction, JR = Job resources, JD = Job demand. The contributions from all variables are significant.

On the other hand, we have added the five endogenous variables: hourly wage, working time per week, experience, grade level, and gender to the original model (see Figure 3). The second model also had a good fit to the data (RMSEA =.071, CFI =. 931, TLI =.903, SRMR = .045). All variables explained 70% of the variance in STEM TJS. However, the results showed that there is no significant difference in TJS between male and female STEM teachers. Also, the variables of STEM teachers' experience and total working hours per week did not have significant contributions to their job satisfaction. The variable of hourly wage has a significant contribution to their job satisfaction (beat = .048). We found only small differences between middle school and high school STEM teachers' job satisfaction. The analysis revealed a small tendency that high school teachers have higher levels of job satisfaction than middle school teachers.

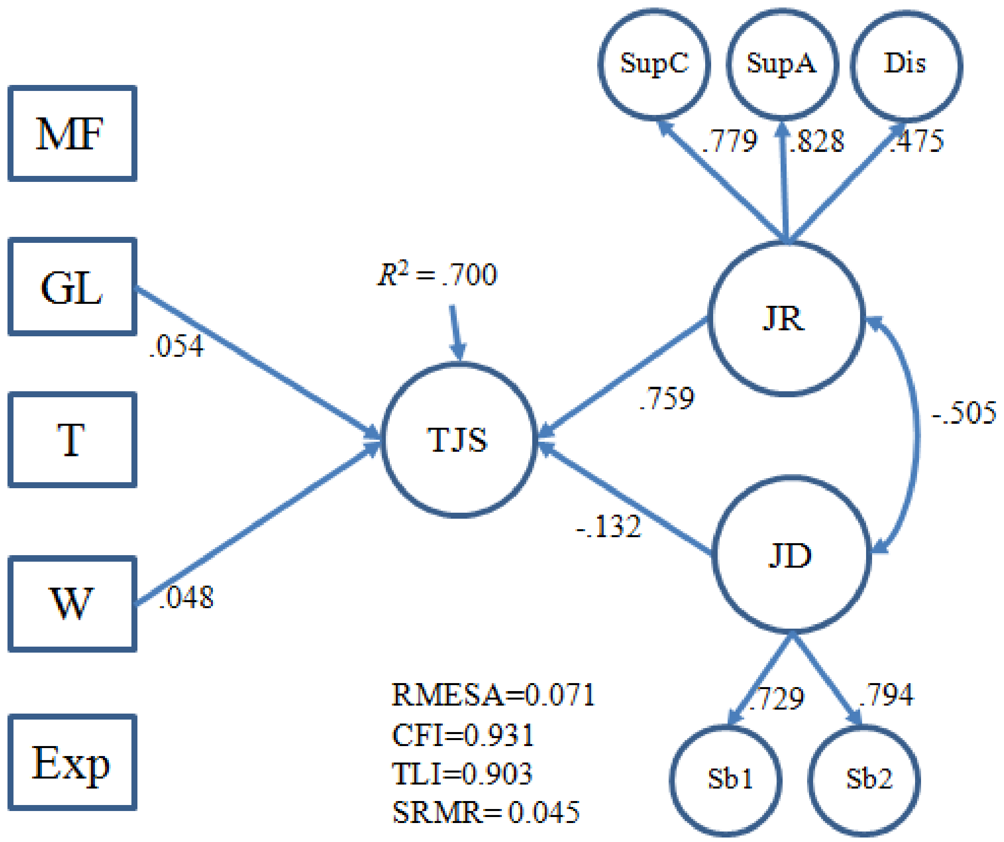

Figure 3. The Second Model of STEM Teachers' Job Satisfaction

Note. MF = Gender, GL = Grade levels, T = Total working time per week, W = hourly wage, Exp=Experience. TJS = Teachers' job satisfaction, JR = Job resources, JD = Job demand. No lines exist between the factors of MF, T, and Exp between TJS means the three factors did not make a statistically significant contribution to teachers' job satisfaction.

Discussion

This study adopted the JD-R model as a framework to examine the effects of job demands and job resources on STEM teachers' job satisfaction. By conducting Confirmatory Factor Analyses to create all latent variables and using the Structural Equation Model to analyze STEM teacher data from SASS 2011-12, we came to the following findings.

First, as we see the good data fit for both models, thus we believe it is appropriate to divide factors affecting STEM teachers' job satisfaction into two categories: job demands and job resources. In this case, the factors that lie in teacher job demands are student misbehavior and students' background, while the factors of job resources include support from colleagues, support from administrators, and distributed leadership. This is a crucial finding because previous researchers have identified many possible factors affiliated with the JD-R model. In a systematic review of the JD-R theory conducted by Schaufeli and Taris (2014), 31 job resources, 12 personal resources, and 30 job demands were identified in the previous studies.

To answer the first research question, we found a robust positive relationship between job resources and TJS (beta=.759) and a moderate negative relationship between job demands and TJS (beta= -.128) by running the first model. Obviously, the job resource is a more significant classification of TJS predictors. This is consistent with prior conclusions on work engagement and variables related to the JD-R model, with job resources being the most significant factor of work engagement (Lesener et al., 2019). In addition, job demands are not as significant as job resources (Halbesleben, 2010; Lesener et al., 2019). According to Lesener et al. (2019), one possible reason for this situation is the difficulty in distinguishing between challenging and hindering job demands.

Another noteworthy finding is that the two factors of job resources (i.e., support from colleagues and support from administrators) have high factor loading while the factor of distributed leadership has a lower factor loading. This is parallel to the outcomes of Hulpia and Devos (2009), who analyzed the impact of distributed management on TJS and organizational commitment. They found that variables related to school leadership were more directly related to teachers' personal loyalty, sense of recognition, and sense of engagement to the school. However, the impact of leadership in schools on teachers' positive emotions such as TJS is weaker.

The second research question is about whether gender affects STEM TJS. According to the data analysis, we found no significant difference in TJS between male and female STEM teachers. This is consistent with a large number of studies examining the effect of gender on TJS (e.g., Aytac, 2015; Crossman & Harris, 2006; Mabekoje, 2009). The reasons for this situation may stem from the paradoxical situation of women as teachers. Despite the disadvantages of female teachers in terms of income, recruitment, resignation, promotion, and career opportunities, teaching is considered to be a more convenient profession for female employees. Possibilities for women to find teaching a convenient profession include teaching that takes place at certain time periods of the year with specific working hours which gives female teachers abundant time and opportunity to handle their personal life, and offers socio-economic independence (Aytac, 2015).

Regarding the third question, teachers' work experience and total working time per week did not contribute significantly to job satisfaction among STEM teachers. However, the hourly wage variable and grade levels they taught made significant contributions to their job satisfaction. The reason that teachers' work experience is not a significant factor is likely due to the respective strengths of teachers who do and do not have teaching experience. The determinants of job satisfaction for inexperienced teachers can be supported by the "honeymoon period" theory. Teachers may embrace more challenges and opportunities that occurred in their early careers, which makes them achieve higher levels of job satisfaction (Reilly et al., 2014). On the other hand, teachers with more work experience may have higher overall TJS due to the positive relationships they build with colleagues over the years and the professional support that may come with, in addition to an accumulation of their successful experience (De Nobile & McCormick, 2006).

Speaking of working hours, we got the same result as Brady's (2021) online questionnaire survey of 806 English teachers: the number of hours worked is not related to TJS in either sector of state and independent schools. According to Will (2019), while U.S. teachers have reported an average weekly working time of 46.2 hours which is well above the international average level of 38.3 hours, the vast majority (90%) of them indicated as satisfied with their jobs. This may be related to the long working hours across all professions: teachers and non-teachers in U.S. schools work approximately the same amount of time during a school year. However, teachers' more than 40 hours of work time in a week is a common phenomenon. The question is whether most teachers would like to accept this fact or hope to change this heavy working load. Meanwhile, it is an urgent fact that the U.S. teachers' attrition rate has been higher than other countries in the last two decades. As educational researchers, we have to explore the real reasons for this finding of the weekly work time and their satisfaction so that we can further contribute to STEM teachers' retention.

Unsurprisingly, teachers' wages are an influential component of determining TJS. According to Will (2019), since the beginning of 2018, dozens of teachers nationwide have protested stagnant salaries and cuts in school funding. Increasing salaries for teachers has been a nationwide issue, and it has appeared in the speeches of several presidential candidates. In addition, when American teachers were asked what they would regard as being their most vital priority if education budgets were raised, nearly 70 percent of them said raising teacher salaries would outweigh any other spending.

In addition, we found a small trend for high school teachers to have higher TJS than secondary teachers, which contradicts both Hughes's (2006) and Pearson and Moomaw's (2005) findings. One possible reason is that high school students are learning about themselves, and more self-disciplined students lead to more satisfied teachers. During and before middle school, students felt safe in their own little communities and were less concerned about the external environment. However, suddenly all changes occur in high school, the goal of going to college becomes very clear and school students need to focus on grades from day one (Cooper, 2021). More studies focusing on teachers' grade level are needed to explore reasons in depth.

Conclusion

This study verified the validity of the developed framework for STEM TJS by analyzing national data. Our study found that the factor of job resources had a significant positive effect on STEM TJS, while the factor of job demands had a generally negative effect on STEM TJS. In addition, higher wage levels can contribute to the significant improvement of TJS. Meanwhile, high-school STEM teachers have higher TJS compared with middle-school STEM teachers.

In general, this study contributes to the two following aspects. First, this study developed a conceptual framework for STEM TJS based on the JD-R theory, which may provide thoughts for future studies to explore the significant factors of STEM TJS. Second, this study confirmed the importance of teachers' hourly wage for STEM TJS. Meanwhile, it is surprising that teachers' experience and weekly work time are not significant factors for STEM TJS. These surprising findings could lead us to explore further about these relationships in the future study.

However, we should mention two limitations in this study. First, this study did not include the factors related to STEM teachers' personalities which could have a significant effect on TJS. Future studies can integrate these factors into the developed framework for STEM TJS. Second, this study only analyzed one-level data from a single year rather than two-level data about cross years. Thus, more studies are crucial to validate the validity of this developed model by analyzing the longitudinal data or two-level data. Third, this study did not employ the latest revised theory of job-resources-demands. In the revised theory, personal resources could be used to explain their job satisfaction. Therefore, personal resources, like self-efficacy, personality, and attitude towards teaching could be involved in the framework for STEM TJS.

Notes

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Chapter 5 - A Case Study of a Female Pre-service Teacher Learning to Code for Mathematics Teaching: Analysing Emotions and Attitudes through a Gender Lens

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Chapter Highlights

- We present a case of a female Canadian pre-service teacher learning to code to support her future mathematics teaching.
- Learning to code for teaching is fraught with experiences of uncertainty, intimidation and overwhelmedness that are influenced by negative stereotypes, a lack of prior exposure to coding, and the vastness of the perceived learning requirements.
- Special attention is needed to support women in coding, in particular women elementary school teachers, who have been dissociating from various forms of ICT (including coding) and who make up a significant portion of the Canadian teaching workforce.
- We extend Hannula's (2002) framework for analysing attitude and changes in attitude to analyze the affectual aspects of learning to code in teacher education.
- Pedagogy that encompasses an ethics of care can offer essential and responsive insights into providing nurturing, supportive, and inclusive professional development experiences that can facilitate learning in a subject area that is perceived as stereotypically unwelcoming, individualistic, and discriminatory towards women.

Introduction

Many North American school jurisdictions have begun to include coding and computational thinking in K-12 curricula. Our own school jurisdiction of Ontario, Canada has just revised our mathematics curriculum for grades 1 through 8 (2020) and grade 9 (2021) to include coding expectations connected to algebraic reasoning every year. A key challenge facing schools is the limited prior experience with, or knowledge of, coding and computational thinking among the teaching workforce. As educational institutions and professional development organizations mobilize initiatives to upskill the workforce, questions emerge around how to best support the diverse needs of this demographic.

Notably, much of our Canadian elementary teaching workforce is women. Yet, since the 1990's in most countries women have been dissociating from actively engaging in many forms of ICT including computational reasoning (Patitsas et al., 2014; West et al., 2019). This poses a new problem for our K-12 education system especially, like in Ontario, when computational reasoning curricular expectations are intertwined with mathematics expectations. Teaching mathematics and developing teachers of mathematics is already fraught with difficulties because of knowledge (Kim et al., 2021; Walshaw, 2012), anxiety (Dowker et al., 2016), and the specific, complicated and cultural pedagogical needs of teaching mathematics (Stigler & Hiebert, 2004). And this complexity to mathematics teaching is even before we have integrated the learning and teaching of computational reasoning into the mathematics curriculum. We need to understand how to support K-12 educators, and especially women, with learning to code for teaching mathematics. We note here that computational thinking (Wing, 2006) is an umbrella term for transferable 21st-century digital skills that leverage technology and information processing for problem-solving (Paul, 2016; Wu et al., 2020). Additionally, it supports the recursive approach to working with and analyzing complex tasks, developing abilities to break down and understand large and abstract concepts (Bers, 2019; Wing, 2006).

While there is scant research on the support of women learning to code in order to teach with coding, we do know from studies around women and ICT that:

- fostering a sense of belonging (Esquinca et al., 2021),
- establishing an identity (Ulriksen et al., 2010) as a person who codes, and

- developing a sense of community (Goos, 2004; Rincón & George-Jackson, 2016)

are vital to the persistence and achievement of women. In our research we are exploring how emotions, identity, sense of community, and sense of belonging develop in order to support learning to code for mathematics teaching by women pre-service teachers (in North America "pre-service teacher" is a term used to identify students in Bachelor of Education programs as they learn to become teachers). In this chapter we report on findings of one case study of a woman, Charlotte (pseudonym), learning to code for mathematics teaching. In our analysis we use Hannula's (2002) framework for analysing attitude and changes in attitude to analyze Charlotte's gendered experience of learning to code. We specifically explore Charlotte's changes in attitude surrounding coding as she learned to code. We begin the chapter with a discussion of the current literature on coding and its importance in the digital economy, the gendered nature of coding experiences and research on introducing coding into teacher education. We then introduce Charlotte and discuss our methods for collecting and analysing data for her case study. In the next section we discuss our theoretical framing. We then analyze and discuss our data and conclude the chapter with recommendations for both teacher education practice for women learning to code and for future research. In our recommendations we specifically discuss the importance of care (Noddings, 2012, 2013) as a response to the gendered spaces in coding education.

Coding and the Digital Economy

Digital literacy is an important skill in the digital economy and has become as critical as literacy and numeracy (Bers, 2019; West et al., 2019; Wing, 2006) to access, upward mobility and inclusion in society. As our technology rapidly progresses, there is a growing need for the development of 21st-century digital literacy skills. This need can of course be seen in the demand for well-equipped computer science majors and programming professionals. However, the digital economy has introduced as great a need for more general digital skills across all fields (DePreyck, 2016), not only those fields usually typically associated with ITC. Given that computing is an integral part of our everyday lives, skills that would enable more meaningful access and engagement with technology (West et al., 2019) are necessary for the creation of digital citizens who can leverage the digital economy (Geist, 2016; Fernandez & Vickery, 2019). West, Kraut, and Ei Chew (2019) argue that without strong digital literacy and control over technology, individuals risk isolation.

One such means of developing digital literacy is through coding education and developing computational reasoning. Today, coding is no longer only reserved for computer scientists (Nouri et al., 2019). Instead, coding is a language and skill that supports the development of computational thinking for all. Notably, coding supports the future STEM workforce (Nouri et al., 2019; Wing 2006), the future of STEM innovation, and the digital economy workforce starting from an early age (Bers, 2019; Popat & Starkey, 2018; West et al., 2019).

Coding as a means of teaching computational thinking extends beyond syntax and text-based operations (DePreyck, 2016). It supports learners' understanding of how computers work and how to control computers through new ways of thinking, creating, and problem-solving (Altun Yalcin et al., 2020; Schmidt-Crawford et al., 2018). Through the development of these skills, learners become informed digital citizens that can be active producers of technology as opposed to passive consumers of technology (Bers, 2019; Popat & Starkey, 2018; Schmidt-Crawford et al. 2018; West et al., 2019).

Despite digital literacy, and subsequently, computational thinking and coding being deemed essential skills of the 21st Century, there is a digital skills gender gap (West et al., 2019) and disparity in the STEM workforce that persists for Women and especially Women of Colour (Denner & Werner, 2020; Fernandez & Vickery, 2019; Martin, 2017). When considering the implications of a gendered digital skills gap, concerns arise surrounding the quality of support and preparation of female teachers in elementary education. Special consideration is needed to address these digital gender gaps to support our female teachers, their teaching practices, and their students developing digital skills.

Women and Coding

Gendered stereotyping of technology continues to steer women and girls away from technology and the computer sciences. This funneling of women away from computer science is perpetuating the gender digital skills gap (Cheong et al., 2021; Cheryan et al., 2013; Fernandez & Vickery, 2019; Lagesen, 2007; West et al., 2019). However, it was not always the case that there was a gender gap in computer science. In actuality, at one time there were more women proportionally than men in the computer science industry. West and colleagues (2019) point to a time just after the Second World War when women were preferred for computing jobs. Since then there has been a genderized shift in the technology field. Recently, technology has come to be considered as a masculine field with male-centered stereotypes consistently reproduced within and around the field (Wilson, 2003). Computing, programming, and ICT as a whole have been dominated by masculine images of power and individualism- leading to exclusion, discrimination, and disinclination for women who want to participate in technology-related fields as they combat stereotypes that are unwelcoming, hostile, or sexist towards them. Women often experience the ICT field as bereft of the affectual affordances that support their growth and development in non-competitive and nurturing (Noddings, 2012, 2013) ways (Herring et al., 2006; West et al., 2019; Wilson, 2003).

In relation to the masculine culture of technology, West et al. (2019) explain that one of the most prevailing disparities surrounds the impact of self-efficacy differences between men and women. However, the differences do not occur through the lifespan. In grade levels across elementary and lower secondary schooling, “the gender gap in actual digital competence is either non-existent or reversed in favor of girls” (p.21). As girls age, their confidence is shown to decrease (Wilson, 2003). Notably, girl’s self-efficacy has shown to decline steadily from mid-elementary school through secondary school. Women consistently demonstrate high levels of digital competency, throughout their lifespan. Nevertheless, because of gender stereotyping, women are perceived to have low skills levels (West et. al, 2019; Wilson, 2003).

While low self-efficacy may contribute to the disparity of women and girls interested in the computer sciences as they grow up (West et al., 2019; Zeldin & Pajares, 2000), access and exposure to computing throughout girl’s lives is lower than their male counterparts (Herring et al., 2006; Wilson, 2003). Herring et al. (2006) explain that despite education’s best efforts to be inclusive to women, societal stereotypes prevail. Perceptions and cultural bias surrounding technology perpetuate disparities in digital literacy and accessibility in schools (Fernandez & Vickery, 2019; West et al., 2019). To combat these disparities, researchers have recommended schools develop consistent and rigorous interventions that start early and are sustained through educational reform and representation (Lagesen, 2007; West et al., 2019).

Additionally, schools that focus on shifting the culture of technology and digital skills away from gendered stereotypes, towards culturally responsive, creative, and inclusive applications of computing in both computer science and everyday life, can better support women in technology environments (Beyer et al., 2004; Fernandez & Vickery, 2019; Wilson, 2003). Schools then, are an important site to support the development and inclusion of girls in coding. Since teachers are so important to schooling, then teachers too, need to be supported in enacting the reform and teaching necessary to create those inclusive computing spaces. The responsibility rests with teacher education and support for the preparation of competent and informed educators that can adequately prepare youth for living and engaging in the digital economy.

Teacher Education and Coding

K-12 teachers are quickly becoming a critical link for future generations, STEM innovation, and the workforce (Baharuddin et al., 2021; Gal-Ezer & Stephenson, 2010) in the development of digital literacies (Wong et al., 2015). Because teachers are so integral to the development of digital literacy skills, there are concerns about teacher perceptions and preparedness when teaching coding and computational reasoning concepts to K-12 students (Nouri et al., 2020; Paul, 2016; Schmidt-Crowford et al., 2018; Wu et al., 2020). Technological innovation may be at risk if thorough measures are not taken to prepare teachers for teaching and supporting students' digital literacy (Wu et al., 2020).

Teacher perceptions have an important impact on teaching methods and lesson content. Subsequently Wu and colleagues (2020) suggest that it is important to both be aware of teachers' perceptions surrounding shifts towards ICT instruction, and to support teachers in developing more positive perceptions of coding. Similarly, Kidd et al. (2020) caution that mandates or policy changes that integrate coding into elementary school curricula alone are not sufficient. They urge for adequate teacher preparation in order for there to be successful computer science integration in classrooms. Ways to support teachers for successful integration include the development of pedagogical strategies (Hubwieser et al., 2013; Martinez, 2010) and the development of a common language to identify best practices (Barr et al., 2011; Gal-Ezer & Stephenson, 2010). Hubwieser and colleagues (2013) outline a framework for teaching computer science concepts in school. Their framework highlights the need for cognitive abilities such as subject knowledge and pedagogical knowledge. In addition to cognitive skills, Hubweiser and colleagues hold that non-cognitive skills such as those that focus on volitional, social, and motivational skills as equally important. Similarly, Paul (2016) argues that strong teacher-student relationships are essential in teaching coding. As discussed in the section on women and coding, these non-cognitive affective aspects are particularly relevant to women in learning to code.

Context and Background: Introducing Charlotte

This qualitative case study research (Stake, 1995) focuses on the affective experiences of a middle school mathematics pre-service teacher, Charlotte, during her introduction to coding and coding pedagogies. Charlotte was enrolled in a 16-month teacher education program that focused on technology in learning and teaching as a defining feature. The teacher education program is promoted as inquiry based, using a blend of face-to-face and online curriculum offerings, and focussing on multiple forms of literacy and essential skills for teaching students in a digital age. The flagship course in the program focused on teaching STEM through coding and included an emphasis on computational thinking practices (e.g., Yadav et al., 2011; Weintrop et al., 2016), how these practices may be fostered in a coding environment such as Scratch ©, and how they may apply to teaching concepts in mathematics and science. At the time Charlotte was completing her teacher education program, our jurisdiction had not yet introduced coding into the K-8 curriculum (that occurred one year after Charlotte graduated). Most pre-service teachers, Charlotte included, have no prior experience coding; it was not part of their school curriculum, and as such, courses that introduce coding for teaching mathematics and science must address coding content, coding pedagogy, and interdisciplinary connections for teaching with coding. Key themes and objectives for the coding education course include fostering critical understandings of the relevance and importance of coding for developing and exploring mathematics concepts and relationships, as well as fostering responsive and reflexive practice that encourages creative and efficient problem solving.

While Charlotte had no prior experience coding, she was enthusiastic to learn Scratch ©, the block-based and user-friendly coding environment popular amongst educational settings. Charlotte was a confident high achiever who identified as a cis-gendered woman of colour. She held a prior undergraduate degree in mathematics and biology and had aspirations of pursuing graduate studies in sciences after her educational studies. Charlotte's advanced background in mathematics set her apart from the other preservice teachers in her program, who primarily held humanities or life science degrees. At the time of her introduction to coding, Charlotte had already completed three semesters of her four-semester program. She had successfully completed two 72-hour courses in mathematics and science methods for middle and high school, as well as a mathematics content course. Each of these courses was technology rich and introduced a variety of technological tools for mathematics learning and science teaching. Charlotte had excelled in her adoption of relevant and powerful educational technology, as well as in her understanding, and articulation, of important principles for student learning. She was active in the school community and student groups and spoke passionately about her desire to affect positive change for how students experience and enjoy mathematics learning.

For this paper, we collected data from Charlotte's personal reflective accounts, produced as spoken-word video reflections and then transcribed, as well as her written responses to the following two questions:

1. As you have been learning to code, what emotions have you experienced? Identify as many as you can. For each emotion, please describe your experiences of that emotion and share any reflections.
2. Think about a moment of real frustration. Tell me about it – what happened, what caused it, what you did about it, etc. Please describe it in as much detail as you can.

Data was analysed using Thomas' (2006) general inductive method, which included an initial reading to familiarize ourselves with the text / transcripts and an initial coding for themes based on Hannula's framework (2002).

Theoretical Framing- Changes in Attitude

We noted in our literature review of the importance of affectual supports that support women learning to code. This is because the culture of coding is dominated by masculine stereotypes of women being perceived as less able than men, by cultural attitudes that privilege competition and by cultural images of individualism and power. Affectual supports can then challenge these stereotypes and cultural images and support women in feeling a sense of belonging and self-efficacy (Johnson & Elliott, 2020). Subsequently, our intentions with this study are to make Charlotte's affectual experiences and tensions explicit. We therefore draw on an analytical framework with affect at its core to help us analyze the affectual aspects of Charlotte's reflections.

We draw on Hannula's (2002) framework for analysing attitude and changes in attitude to analyze the affectual aspects of learning to code in our case study. Hannula develops the concept of attitude as consisting of emotions and cognition. Internally, a person constantly gauges their own cognitive goals through the (learning) situation they are experiencing. Emotions are the manifested results of this active gauging. Thus, cognition and emotions are intertwined but with distinct, recognizable phenomenological characteristics. This distinction allows the framework to be operationalized as an analytic tool, as both emotions and cognition are ever-present and intertwined in our psyche. However, it is only when we experience emotions as an intense response that they can become identifiable, and thus the subject for analysis.

Hannula (2002) has theorized four categories of attitude that can be analysed. The first category is *emotions experienced as a response in the midst of an experience*. These emotions are in-the-moment responses and are not necessarily developed from prior experiences. Some examples of these types of emotions might be the response someone has to an efficient salesperson or to someone holding a door open. When someone has an immediate response to these incidents that are not based on prior experiences, they are experiencing Hannula's first category of emotions.

The second category is e*motions that result through making connections to the stimuli*. As opposed to the first category, emotions from the secondary result directly from prior experiences. These responses can also be in-the-moment, however in this case a person is considering their experience against prior experiences and making subsequent connections. In his article, Hannula relates this type of emotional response to when people experience negative attitudes towards mathematics because of negative prior experiences. We can draw the same connection to learning to code. Women may have had negative prior experiences with coding, or more likely, are influenced by negative stereotypes. Subsequently, when introduced to the idea of learning to code, women might experience the second category of emotions as a result of these prior experiences.

The third category is *emotions resulting from the anticipated ramifications of interacting with* *the environment or experience*. When experiencing this category of emotions people can create mental scenarios that extend from the situation at hand and result in the experience of emotions. An example of this type of emotional experience might be if a child experiences emotions as a result of being presented with a test. The child might create a scenario in their mind where they do poorly on the test and subsequently experience emotions as a result of the possibility of doing poorly. In this child's case, the test is a catalyst for the scenario, and they experience emotions as a result of the scenario.

The final category is *emotions experienced when connecting the experience back to personal goals and values*. An example of this category might be if someone has an equity goal of creating an app to help people in need find housing. The person may experience learning to code as difficult but their emotions as a result of the difficulty are balanced in relation to their goal of creating the app.

Hannula's (2002) framework for analysing attitude and changes in attitude is a theoretical framework originally developed for the study of affect in mathematics education. Because the purpose of our study is to understand the affectual norms that support the persistence of women pre-service teachers learning to code, we extend the applicability of this framework by considering affective experiences in coding education.

Results and Discussion

Charlotte experienced a range of emotions during the start of her journey learning to code. Of Hannula's (2002) four categories of attitude, we found most of Charlotte's emotions could be described as:

- emotions experienced as a response in the midst of an experience, and
- connecting the experience back to personal goals and values.

In order to situate our analysis of the category of responsive emotions, we begin our analysis with the category of personal goals.

Personal Goals

Charlotte's personal goals were deeply connected to her prior experience with high achievement and to her beliefs about her own expertise. In our Ontario teacher education system, Charlotte was considered a “subject expert” because of her prior four-year undergraduate degree in mathematics and sciences. The majority of elementary and middle school pre-service teachers in Charlotte’s program held general humanities or life science degrees, and there is no specific prerequisite number of courses in any particular subject matter area for admission into the program. As a result, most elementary and middle school pre-service teachers have little to no post-secondary education in mathematics and science. In contrast, the majority of undergraduate courses Charlotte took were in biology and mathematics. She was very confident in her subject matter knowledge and was keen to develop pedagogical skills. Charlotte expected the focus of her learning in the teacher education program to be on new pedagogical approaches for familiar content. In her reflections, Charlotte noted that in her coursework in biology and mathematics she was re-learning (Pournara & Adler, 2014) familiar content. In contrast, Charlotte had never coded before and subsequently, the experience of learning to code was completely new with completely new content.

Charlotte noted that she expected to earn high grades, like she did in her undergraduate degree. She opined that she “placed an immense pressure” on herself to meet the “grand expectations” she had set for herself. Indeed, Charlotte’s experience of learning to code conflicted with her personal goals of achievement. Specifically, Charlotte experienced tension with her beliefs about her own expertise and her expectation for high achievement. This occurred especially in the initial stages of learning to code when Charlotte felt frustration that she:

> “wasn’t able to produce any ‘good’ sequences of block code that I held to my own standards.”

In the initial stage, Charlotte was determined to meet her personal goals of succeeding in developing coding skills despite the initial frustrations of learning a new topic. However, learning to code required effort and time, and Charlotte worried that both would impede on her other commitments in her teacher education program:

> “especially because I knew that this time would be taking away from time with which I could be efficiently completing school homework, assignments, etcetera.”

Nevertheless, Charlotte reflected on the different experience of learning to code versus learning other material in the program. She described herself as "a linear thinker, learning from the bottom-up with each new concept building on the last" and expressed envy at the "well of knowledge already established" by young learners. She sought out resources and strategies that would help her "in focusing [her] efforts" and "honing" her skills. As Charlotte began to persevere through the initial tensions between learning to code and her personal goals, she conveyed responsive emotions surrounding her process.

Responsive Emotions

Charlotte organized her reflections by labelling and describing her responsive emotions. These specific emotions must have been quite powerful for her because it is only when we experience emotions as an intense response that they can become identifiable (Hannula, 2002). Like other women learning to code (West et al., 2019), Charlotte experienced tension in her emotions. These tensions related to the gendered experiences that women experience in developing their reasoning skills around coding. Charlotte identified feelings of excitement, uncertainty and overwhelmedness, and fulfillment and relief.

Excitement

Charlotte experienced excitement in the middle of coding as a result of anticipation of a successful outcome in the process of coding:

> "When I am in the middle of putting a sequence of code together with a variety of blocks, I tend to get excited, especially after testing it and checking the progress of what it is that I want it to ultimately do."

and after struggling through moments of being stuck:

> "It is the most exciting thing in the coding world to finally figure out how to make that darn code work."

Both types of excitement that Charlotte experienced, resulted in her being supported to further persevere through difficulties. Research (e.g., Lin, 2016) has suggested that perseverance eventually leads to developing feelings of self-efficacy. In both types of cases where Charlotte experienced excitement, Charlotte's excitement helped her persevere through her initial tensions and frustrations. Importantly, both were linked to moments of accomplishment that led to new coding possibilities.

Uncertainty and Overwhelmedness

Charlotte's responsive emotions of uncertainty and overwhelmedness manifested more intensely in the beginnings of her experience of learning to code. These emotions were as a result of gendered cultural beliefs around coding. Even before Charlotte started the process of learning to code, she had preconceived notions of what it meant to code. Charlotte admitted that she had a "negative, disciplinary narrative going on in my head." That is, Charlotte was influenced by the cultural and gendered narrative that coding would be difficult for her. Additionally, Charlotte was influenced by other cultural notions of coding. When she thought of coding, she envisioned complex and "syntax heavy" codes. She described:

> "just the idea of being... required to code brought on feelings of being overwhelmed."

Ultimately Charlotte experienced uncertainty and overwhelmedness because she worried that she would fail at the task of coding and disappoint the research team. In her reflections, Charlotte shared a list of her initial questions that conveyed her uncertainty:

- Am I going to understand the coding tasks?
- Am I going to be able to keep up with the learning of coding and coding-project deadlines?
- Can I handle all of this?!
- Am I going to be an asset or a hindrance to this project and my team?

Charlotte's uncertainty and overwhelmedness continued into her beginning stages of learning to code when she was faced with multiple open choices:

> "the number of options available for selection and inclusion in the code contributed to this feeling of being overwhelmed, paired with intimidation."

As Charlotte continued with learning to code her emotion of overwhelmedness disappeared, while her emotion of uncertainty was experienced on a lesser level:

> "As I continue(d) working, there (was) still a level small level of uncertainty that I felt."

This experiencing of both overwhelmedness and uncertainty at the beginning and only uncertainty as coding development progressed is an important distinction. If Charlotte had experienced overwhelmedness through her entire process, we wonder if she would have continued learning to code despite her personal goals of doing well- the sense of being overwhelmed is not a pleasant experience. Additionally, women who have left the field of ICT have reported the sense of being overwhelmed when learning to code (Pantic & Clarke-Midura, 2019). Yet significantly, Charlotte's sense of being overwhelmed dissipated and was replaced with self-confidence and stronger beliefs in her own abilities:

> "frankly I am surprised at how not scary this whole endeavour has turned out to be. I must be more competent that I give myself credit for! I have been learning a lot, I have been enjoying myself, and I have been experiencing successes, even if they are small ones."

At the same time that overwhelmedness can hurt retention and learning, a sense of uncertainty can be a significant support for learning. Uncertainty can propel learning forward (Zaslavsky, 2005). Charlotte shared this when discussing how her questions progressed from ones about her own ability at the beginning of her learning, to questions related to problem-solving around coding:

- Will I figure out how to create a script to achieve "X" goal?
- Can I figure out the script within my given timeline?

Fulfillment and Relief

Charlotte's journey through learning to code was a tumultuous one- emotionally. Charlotte was influenced by cultural stereotypes about coding, she experienced excitement, overwhelmedness and uncertainty. Yet, as we learned from Charlotte as she explained her fulfillment and relief, all these emotions were rooted in growth and development for her.

At the end of her reflections and without a special prompt, Charlotte discussed her growth and fulfillment through her process of inquiry, with an eye toward her future growth. For Charlotte the responsive emotions of fulfillment and relief were related. Charlotte situated herself in looking at what she accomplished and accounting for past learning experiences, exploring future goals, and deciding on the strategies she needed to accomplish these goals. She described making "real progress... when I started to experiment" and noted that:

> "with each subsequent test of the code, I became more enthralled."

At the end of the process Charlotte shared her new "commitment" to learning how to code and her belief in the importance of setting aside time to learn to code. She appreciated the value of using her own journey as a model for understanding her future students:

> "There is great value of being able to understand the learning curve of using ourselves in order to facilitate learning of this curve in our students."

Charlotte also drew a direct connection between her own experiences of learning to code and her future teaching practice:

> "These experiences allowed (me) to build empathy for our students, develop different pedagogical possibilities to tailor lessons for various learners and learning needs, and deepen (my) current knowledge and perspectives."

Conclusion

In this chapter, we apply Hannula's (2002) framework for analysing attitudes and changes in attitudes to the new area of coding teacher education. Our research offers an important theoretical contribution and first step into the study and analysis of teachers' affective experiences when starting out in this new area of their professional development. As school jurisdictions increasingly look to introduce coding and computational thinking into K-8 curricula (e.g., Benton et al., 2017) there is a need to know more about how to best support teacher learning in coding, especially women teachers who make up the majority of the K-8 school workforce. Charlotte's case offers important insights into the initial learning experiences of teachers learning to code for teaching. Her confidence and advanced mathematics and sciences background sets her apart from other pre-service elementary teachers who tend to have taken few if any undergraduate courses in the subjects. Nevertheless, Charlotte experienced tensions, uncertainty, and overwhelmedness at the prospect, and early stages, of learning to code. Charlotte's case highlights the precariousness of attitudes related to self-efficacy, belonging, and identity, and emphasizes the importance of supportive early experiences when learning to code.

In line with prior research (e.g., Esquinca et al., 2021; Goos, 2004; Rincón & George-Jackson, 2016; Ulriksen, et al., 2010), identifying as a person able to successfully code was important for Charlotte's sense of belonging in a community of coding educators and impacted her persistence in the face of overwhelming uncertainty. Charlotte's feelings of intimidation and overwhelmedness emerged despite her established and professed identity as a mathematical and scientific person. Establishing an identity as a person who codes was distinct for Charlotte. Stereotypes of syntax-heavy coding environments influenced her expectations and self-imposed pressures related to balancing and achieving her professional goals and elicited early resistance and feelings of trepidation. Charlotte had to face the question of whether her efforts to learn to code were "worth it" given that it would take away from other learning and professional development - there was a significant time commitment involved and the negative emotions experienced especially in the early stages were draining. Charlotte's identity and sense of belonging as a person who codes emerged slowly over the course of small successes and accomplishments and was bolstered by her overarching sense of self-efficacy and confidence.

Hannula's (2002) attitude framework for mathematics learning provided a useful framework for identifying and analysing Charlotte's responsive emotions to coding in light of her expressed personal goals. Our analysis also suggests ways in which attitudes and emotions about coding education are different from mathematics education. Specifically: limited previous experience with coding content and with "applications of coding in the classroom setting." That is, both the content and its associated classroom enactment are new, and teachers' awareness of their limited experiences and the limited supports currently available in schools can contribute to experiences of negative emotions.

Our research suggests that being explicit with positive encouragement, technical and troubleshooting support, and reinforcement of "small" successes can help individuals manage and overcome these feelings. However, for teachers who struggle more generally with feelings of anxiety in mathematics and sciences, a more nuanced approach may be needed. In applying Hannula's framework to coding education, we provide a window into some of the attitudes and emotions experienced by individuals who may well pioneer educational coding for mathematics learning in their future schools and call for more research into this important area.

Recommendations

We see parallels in the emotions experienced by pre-service teachers in mathematics education; uncertainty can lead to fear and frustration, particularly when individuals feel outside of their "comfort zones", and excitement and fulfillment can have both technical (content-based) and personal (relationship-based) dimensions. Given the high proportion of women elementary school teachers (in North America), and their wide-spread experiences of marginalization in STEM fields, we suggest that professional development initiatives include responsive pedagogical approaches which attend to and support the affectual experiences of individuals learning to code.

When considering the gendered culture of technology and the development of inclusive strategies for teachers, women, and girls, connections can be made to feminist ethics and ethics of care. On a large scale, parallels can be drawn between the masculine gendered stereotyping associated with technologies (Herring et al., 2006; West et al., 2019; Wilson, 2003) and feminist ethics that stand in opposition to those beliefs (Gilligan, 1993). Additionally, commonalities can be seen with Noddings' (2012, 2013) ethics of care in calls for responsiveness and attentiveness to women, students, and teachers alike in implementing ICT concepts in education.

Gilligan (1993) suggests that in a justice-centered perspective, masculinity depends on themes of individualism, independence, and "seeing other persons and intimate relationships as dangers or obstacles to pursuing those values" (Norlock, 2019, para. 2.2). However, in a feminist ethics of care, the self is relational and contextualized by the needs of others as opposed to the individual (Koehn, 2012; Noddings, 2012; Norlock, 2019). A relational ethics of caring is situated between the caring and cared for (Noddings 2012, 2013). It is focused on interdependent concepts of responsiveness and attention towards the needs of the cared for, and responsiveness to caregivers (Cheong et al., 2021; Noddings, 2013). In addition, these principles extend to structural systems. Noddings (2013) explains that structural barriers may impede caring relationships to form. She encourages the inclusion of caring practices in order to transform environments that may prohibit inclusive, responsive, and trusting relationships to form.

In the context of computer sciences and the culture of technology, power-focused and individualistic stereotypes (Herring et al., 2006) can be viewed in opposition to feminist ethical caring environments and the potential resistance women feel to the field despite intervention. Cheong et al. (2021) suggest that caring ethics should look beyond masculine biases to address prevailing inequities in computer sciences. Strategies for teaching ICT concepts in elementary and secondary schools that rely heavily on relational support from teachers (Hubwieser et al., 2013; Paul, 2016) alongside responsive and inclusive educational reform for women (Beyer et al. 2004; Fernandez & Vickery, 2019; Wilson, 2003) are essential practices that extend beyond computing content knowledge. They are essential in that they extend towards nurturing, caring, and inclusive environments that aid in learning in an otherwise unwelcoming environment.

Future Directions and Limitations

One of the limitations of this research is that our case study is a small sample space. Our research is an entry point to understanding how emotions affect how female pre-service teachers learn to code for teaching. Future research should include a larger and varied sample to understand how emotions might change with different populations of pre-service teachers. Our study included a pre-service teacher learning to teach middle school. Therefore, of particular interest for future research would be to include pre-service teachers learning to teach coding spanning Kindergarten to college. Of note Charlotte felt confident with mathematics and the prospect of teaching mathematics. A future research area would be to explore emotions of pre-service teachers who feel anxiety with the prospect of teaching mathematics.

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Chapter 6 - Investigation of STEM Awareness Levels of Classroom Teacher Candidates in Terms of Problem Solving and Gender Variables

Ayten Pınar Bal

Chapter Highlights

- In this study, it was concluded that there is no significant difference between the awareness of classroom teacher candidates who have different problem solving success towards STEM and those who have similar views towards STEM.
- As a result of this study, it was concluded that female participants' awareness of STEM is higher than male participants in terms of gender and problem solving success.
- Classroom teacher candidates should have positive views on STEM in order to enable them to gain problem-solving skills in their future professional lives and to understand their perspectives on science, technology and mathematics.
- It has been concluded that classroom teaching practices that will positively affect classroom teacher candidates' awareness of problem solving and STEM. In addition, it should be given importance to the teaching environment which is important factor in the learning of science and mathematics in the undergraduate education.

Introduction

In recent years, individuals' adaptation to the age they live in depends on adopting scientific thoughts and turning to scientific research in this field. In this process, which enables the application of scientific knowledge to daily life and its transformation into new inventions and products through education; STEM education emerges as an approach that enables teaching and learning by integrating the fields of Science, Technology, Mathematics and Engineering together (Gonzalez & Kuenzi, 2012; Howard-Brown, Martinez, & Times, 2012). In this process, in addition to providing students with the opportunity to use STEM education, research-inquiry, innovation, production, and scientific research methods in daily life through education (Rogers & Portsmore, 2004; Dugger, 2010) to their scientific knowledge from different disciplines and gaining their knowledge from different disciplines. It also allows for adaptations (Bybee, 2010; Roberts, 2012; Çorlu, Capraro & Capraro, 2014; Moore & Smith, 2014). From this point of view, with STEM education, it is of great importance to create areas where students can use the theoretical knowledge they learned at school in real life and to provide them with the knowledge and skills to produce solutions to the problems they may encounter in the future (Capraro & Slough, 2008; Bybee, 2010; Dugger, 2010; Thomasian, 2011; Karakaya & Avgın, 2016). Again, as an interdisciplinary process, STEM education stands out as an important element in the formation of critical thinking and the development of creative problem-solving skills in students (Roberts, 2012). In this context, many researchers point out the importance of STEM education covering all education programs starting from pre-school education to higher education (Gonzales & Kuenzi, 2012; English, 2017).

Mathematical thinking, which is the basis of science, technology and engineering fields that make up STEM education, also plays an important role in mathematics programs (Fitzallen, 2015; Rozgonjuk et al., 2020). From this point of view, it is striking that mathematical thinking is an important factor for students' future success and careers (Claessens & Engel, 2013). In the process of developing mathematical thinking skills of students, mathematical processing skills may differ depending on age groups. The reasons for these differences can be shown as students' perception of mathematics as difficult and unnecessary (Fritz, Haase, & Räsänen, 2019), insufficient prior knowledge of students (Grotenboer & Marshman, 2016), or students' low interest in mathematics (Frenzel et al., 2010). In order to overcome these problems, it is of great importance to make students understand the importance of mathematics in daily life (Li & Schoenfeld, 2019), to carry out practical activities in the classroom and to provide technology-based teaching in this process. In this context, STEM education is an important factor for students to be more active in the classroom, to associate mathematics with real life and other fields, and to use technology (Stohlmann, 2018). With STEM education, students are allowed to learn mathematics in a meaningful and permanent way and to develop high-level thinking skills.

On the other hand, from the point of view of mathematics education, it is clearly seen that mathematical thinking, which forms the basis of STEM education, is an important factor for students' future success and careers (Claessens & Engel, 2013; Shaughnessy, 2013; Honey, Pearson & Schweingruber, 2014; English, 2016; Rozgonjuk et al., 2020; Stohlmann, 2019). In this context, when the studies in the literature examining students' STEM awareness levels in terms of problem solving and gender variables (Roberts, 2012; Lin et al., 2015; Öner & Capraro, 2016; Pekbay, 2017; Ince et al., 2018; Prawvichien, Siripun & Yuenyong, 2018; Öner & Yılmaz, 2019) are examined, it is seen that these studies focus on STEM awareness level and problem solving or on STEM awareness level and gender variables (Knezek, Christensen & Tyler-Wood, 2011; Modi, Schoenberg, & Salmond 2012; Cooper & Heaverlo, 2013; Christensen et al., 2014; Kong, Dabney & Tai, 2014; Christensen & Knezek, 2017; Ertem Akbaş, Cancan & Balcı, 2019; Özdemir & Cappellaro, 2020). However, within the scope of the accessible literature, no study has been found that examines students' STEM awareness levels in the context of problem solving and gender variables.

In this context, for example, Prawvichien et al. (2018) examined the effect of STEM activities on mathematical problem solving skills through observation and interview in their research conducted within the scope of a high school mathematics course. As a result of the research, they found that STEM activities improved students' mathematical problem-solving skills. Again, Roberts (2012) concluded that STEM education contributes positively to students' ability to solve problems related to daily life. In addition, Ince et al. (2018) also revealed in their studies that STEM-based activities positively affect students' problem-solving skills. Similarly, Öner and Yılmaz (2019) concluded in their study that there is a positive and significant relationship between students' perceptions of problem solving skills and their views on STEM. Lin et al. (2015) also concluded that high school students' STEM education improves their problem-solving skills. However, contrary to the research findings mentioned above, Pekbay (2017) revealed that STEM activities generally increase student achievement, but do not have a significant effect on mathematics achievement, as a result of her study examining students' problem solving skills and STEM interests. Similarly, Öner and Capraro (2016) found that the problem solving levels of the students in both groups were close to each other, as a result of their study in which they compared the success of students who received STEM education in the classroom and other students who did not receive this education. On the other hand, when the studies on STEM education and gender variable are examined in the literature, there are studies showing that male students are more successful in STEM than female students (Christensen & Knezek, 2017; Christensen, et al., 2014; Kong et al., 2014; Öner et al., 2014) and studies pointing to the opposite of this situation (Knezek et al., 2011; Modi et al., 2012; Cooper & Heaverlo, 2013; Ertem Akbaş et al., 2019; Özdemir & Cappellaro, 2020).

In this context, for example, in the study of Christensen and Knezek (2017), in which they examined secondary school students' interest in STEM and their careers in STEM, it was found that male students were more interested in STEM than female students and they wanted to make a career in these fields more have reached their conclusion. Similarly, Kong et al. (2014) in their study, in which they examined secondary school students' interests in STEM fields before joining the STEM camp, concluded that male students were more interested in STEM than female students. However, contrary to the above-mentioned research results, Cooper and Heaverlo (2013) found that female students attach more importance to STEM education than male students in their study. They also revealed that female students were more successful than male students in problem solving skills at the end of STEM education. Similarly, Modi et al. (2012) reported that female students were more interested in STEM education than male students; again, they found that female students had higher problem-solving skills than male students. Again, Ertem Akbaş et al. (2019) also revealed in their study that secondary school students had a higher interest in STEM fields, especially among female students. On the other hand, Özdemir and Cappellaro (2020) concluded that the gender variable did not cause a significant difference according to the STEM awareness levels of classroom teachers. As it is clear from these findings, in the studies conducted in the literature, gender and problem solving do not indicate a common result in raising awareness about STEM. Also, it can be said that STEM awareness levels are not effective in terms of problem solving level and gender interaction.

As can be clearly seen from the studies mentioned above, when the studies in the literature examining students' STEM awareness levels in terms of problem solving and gender variables are examined, it is seen that these studies focus on STEM awareness level and problem solving or on STEM awareness level and gender variables. However, within the scope of the accessible literature, no study has been found that examines students' STEM awareness levels in the context of problem solving and gender variables. Based on this fact, the main purpose of this study is to examine the STEM awareness levels and problem solving levels of classroom teacher candidates, who are expected to have the most important responsibility in gaining and developing basic problem-solving skills to students in the primary education process, in terms of gender variables. In line with this general purpose, answers to the following questions were sought in the study:

1) Is there a significant difference between STEM awareness levels of classroom teacher candidates with low and high problem-solving skills?
2) Do the level of problem solving and gender interaction cause a significant difference in the STEM awareness levels of classroom teacher candidates?

Method

Research Model

This study was designed according to the causal comparison model in order to examine the STEM awareness levels of classroom teacher candidates in terms of the gender variable of problem solving skills. Causal comparison research is the process of determining the variables that explain the cause and effect relationship of an existing situation and that are thought to be effective on this cause (Cohen, Manion & Morrison, 2011; Büyüköztürk et al., 2019). In this study, STEM awareness levels of classroom teacher candidates; problem solving and differentiation status according to gender variables were examined. While designing the research, "STEM Awareness Scale" was taken into consideration as dependent variable and "Problem solving skill level" and "gender" as a independent variables.

Study Group

The study group of the research consists of third year participants attending the Department of Classroom Teaching in the 2019-2020 academic year of a state university located in the south of Turkey. A sample was not determined in the determination of the study group; 127 third grade participants who answered both of the data collection tools and successfully completed the "Basic Mathematics I-II and Mathematics Teaching I" courses were included in the application. The most important factor in determining the participants who have successfully completed the "Basic Mathematics I-II and Mathematics Teaching I" courses as the study group is primarily the numbers, ratio-proportion, algebraic expressions, equations and inequalities that are necessary for the problem solving skills of these participants depending on the main theme of the research. It is thought that they have such prior knowledge. The distribution of the demographic characteristics of the participants participating in the research is presented in Table 1.

Table 1. Demographic Characteristics of the Study Group

Variables		N	%
Problem Solving Success	Low	42	33.1
	Medium	42	33.1
	High	43	33.8
	Total	127	100
Gender	Female	88	69.3
	Male	39	30.7
	Total	127	100
Achievement in Mathematics	Low	30	23.6
	Medium	70	55.1
	High	27	21.2
	Total	127	100

As seen in Table 1, 33% of the study group had low and moderate problem solving success, while 34% had high problem solving success. In terms of gender, 69% of the study group is female and 31% is male. When examined in terms of mathematics achievement, 24% of the participants are at low, 55% at medium and 21% at high level.

Data Collection Tools

"STEM Awareness Scale" and "Problem Solving Test" were used to collect data in the research. Information about these measurement tools is as follows:

STEM Awareness Scale: In the study, the "STEM Awareness Scale" developed by Buyruk and Korkmaz (2016a) was used to determine the awareness of undergraduate students about STEM. Within the scope of the validity of the scale, a structure consisting of two dimensions was obtained by applying exploratory and confirmatory factor analysis. These sub-dimensions include a total of 17 items as "positive view" (12 items) and "negative view" (5 items). Within the scope of the reliability of the scale, the Cronbach alpha value is .93, .81, and .93 for the whole, respectively. The internal consistency coefficients calculated for this sample are .74, .69, and .92 for the whole, respectively.

Problem Solving Test: A Problem Solving Test was developed by the researcher regarding the daily life that the classroom teacher candidates can solve by using their four operations skills. In this context, a problem test consisting of a total of 8 questions covering numbers, four operation problems, equations and inequalities within the scope of Basic Mathematics and Mathematics Teaching was prepared. The prepared problem test was presented to the opinion of two experts in the field of mathematics education and evaluated in terms of its suitability for the purpose of the research. Considering Cohen's Kappa coefficient, the agreement between expert opinions as .90 is an indication that this result is sufficient (Landis & Koch, 1977). In the next stage, it was decided to review the two questions in the test in accordance with the feedback received.

In this context, for example, it was decided to verbally emphasize the numeric expressions in problem 2 in the draft form. Again, it was decided to rearrange the part of the expression in problem 5, which is thought to cause expression disorder. In the next stage, the test, which was rearranged in line with expert opinions, was piloted to six fourth grade students who successfully completed basic mathematics and mathematics teaching courses. During the application process, the students were informed about the study and their opinions on whether there was an expression they did not understand in the problems were asked and it was determined how long they could solve the test. Accordingly, there was no problem in understanding the problems and in terms of time; The problem solving test was completed in about 30 minutes. As an example, the 5th problem in the test in question is as follows:

"5) Teacher Ali told his students in the 30-question math test that they would gain 4 points for each correct question and would lose 2 points for each wrong question. According to this, how many questions did Ayşe answer correctly, receiving 80 points by answering all the

questions in the math test?"

On the other hand, at the end of the application of the problem solving test, item analysis was calculated and item difficulty level (pj), standard deviation (sj), discrimination index (rjx) and independent samples t-test were applied respectively for 27% of the upper and lower groups. Table 2 shows the data obtained as a result of item analysis.

Table 2. Item Difficulty Levels (pj), Standard Deviations (sj), Discrimination Indices (rjx), t and p Values of the Problem Solving Success Levels Test

Question No	pj	sj	rjx	t	p
1	.56	.47	.41*	-4.77	.000
2	.37	.46	.52*	-3.88	.000
3	.54	.47	.41*	-3.88	.000
4	.34	.45	.35*	-2.65	.010
5	.65	.45	.37*	-3.67	.001
6	.62	.46	.48*	-5.45	.000
7	.45	.47	.45*	-5.13	.000
8	.53	.48	.50*	-6.27	.000

In Table 2, it is seen that the item difficulty value of the problems varies between .34 and .62, and the discrimination value varies between .35 and .52. Accordingly, it can be said that two of the questions are difficult (2nd and 4th), two of them are easy (5th and 6th), and the others are of medium difficulty. On the other hand, it can be said that the level of validity of the discrimination of all questions is sufficient. In addition, it is clearly seen that the KR-20 reliability value of the test is .81 and the test has an acceptable reliability. On the other hand, in the scoring of the problem solving test, "1" point was given to each correct answer and "0" point to the wrong or empty answer. Then, the number of correct answers to the problems as a result of coding was converted into standard scores. In the process of converting raw scores to standard scores, t standard score type was applied by making use of the literature (Tekin, 2010; Baykul & Güzeller, 2013). Then, the scores obtained from the problem solving test were standardized to determine the upper and lower groups, and if the t score was <40, it was classified as low problem solving level, and if t score >60, it was classified as high problem solving level.

On the other hand, during the data collection process, the "STEM Awareness Scale", the "Problem Solving Test" and the personal information form (gender, mathematics achievement) were applied by the researcher to classroom teacher candidates who volunteered to work within the scope of Teaching Mathematics II course in about one hour in the spring semester of 2019-2020. The completion of the STEM Awareness scale and personal information form was completed in about 10 minutes, while the problem-solving test was completed in about 30 minutes.

Data Analysis

In the research, the data were analyzed using the SPSS 22.0 package program. Again, independent samples t-test and two-way ANOVA were used in the analysis of the data. Before applying the analyzes, the normality of the data and the equality of variances were tested. In this context, the Kolmogorov-Smirnov test obtained from the variables for each group was examined for skewness and kurtosis values. In this context, it was concluded that Kolmogorov-Smirnov (KS) value provided the normal distribution for each group. In addition, the normality assumption at each group level, skewness and kurtosis values were calculated and determined to be in the range of -1 to +1. The fact that these coefficients are between -2 and +2 indicates that the distribution is normal (George & Mallery, 2010; Hair et al., 2010). On the other hand, in order to apply the ANOVA analysis, the homogeneity between the variances of the groups as well as the normality distribution was also tested with the Levene test. Accordingly, it was concluded that there was no significant difference between the variances of the groups (Büyüköztürk, 2018; Can, 2014). On the other hand, the effect size (eta squared) values were also examined in the study. The effect size was defined as small, medium and large, respectively, in response to .01, .06 and .14 values (Büyüköztürk, 2018).

Results

The findings obtained in line with the sub-problems of the research are given below. Accordingly, Independent samples t-test analysis was applied to determine whether there is a significant difference between STEM awareness levels of classroom teacher candidates with low and high problem solving success levels. The results of the analysis applied to the STEM awareness scale are shown in Table 3.

Table 3. Independent Samples t-test Results on STEM Awareness Levels of classroom teacher candidates with Low and High Problem Solving Success Levels

Dimensions of STEM Awareness	Problem Solving Success Level	N	$\overline{X}$	S	sd	t	p	Eta-Square
Positive Perspective	Low	42	4.31	.47	83	.683	.411	.008
	High	43	4.23	.47				
Negative Perspective	Low	42	1.81	.49	83	.219	.641	.003
	High	43	1.86	.59				
Total score	Low	42	3.11	.33	83	1.393	.241	.017
	High	43	2.79	1.73				

As seen in Table 3, it is seen that there is no significant difference between graduate participants and low problem solving success in terms of STEM awareness dimensions and total score (Positive Perspective $t_{(83)}$=.683, p>.05; Negative Perspective $t_{(83)}$= .219, p>.05; Total score $t_{(83)}$= 1.393, p>.05). Accordingly, it can be said that the STEM awareness levels of participants with different problem-solving skills are close to each other. In addition, the effect size analysis shows that the values obtained affect STEM awareness levels at a low level (Büyüköztürk, 2018).

In the second sub-objective of the study, a two way (2x2) ANOVA test was applied to determine whether there was a significant difference between classroom teacher candidates awareness of STEM in terms of problem solving level and gender interaction. Analysis results are presented in Table 4.

As seen in Table 4, it is seen that there is a significant difference in terms of problem solving level and gender interaction in terms of STEM awareness total score. [Total score F(1-81)= 9.915, p<.05). Accordingly, it can be said that female participants who are successful in problem solving have higher awareness of STEM than male participants. On the other hand, it can be said that the opinions of male and female participants who have different problem solving success in terms of positive and negative perspective sub-dimensions of the STEM awareness scale are close to each other. In addition, the effect size analysis shows that the obtained values affect the STEM awareness total score moderately (Büyüköztürk, 2018).

Table 4. Two Way (2x2) ANOVA Test Results of Problem Solving Success Level and Gender Interaction on Classroom Teacher Candidates' STEM Awareness Level

Dimensions of STEM Awareness	Problem Solving Success Level (P)	Gender (C)						sd	F (PxC)	p	Eta-Square
		Female			Male						
		N	$\overline{X}$	S	N	$\overline{X}$	S				
Positive Perspective	Low	29	4.32	.39	13	4.32	.64	1	.105	.747	.01
	High	28	4.26	.41	15	4.18	.58				
Negative Perspective	Low	29	1.82	.51	13	1.80	.46	1	.032	.858	.00
	High	28	1.87	.62	15	1.85	.54				
Total score	Low	29	3.14	.38	13	3.06	.20	1	9.915	.002	.11
	High	28	3.39	1.26	15	1.67	1.96				

(PxC): Problem solving success level x Gender interactional effect

Discussion

This study was conducted to examine the STEM awareness levels of classroom teacher candidates in terms of gender variable of problem solving skills. In this context, it was concluded that the STEM awareness levels of classroom teacher candidates with low and high problem-solving skills were close to each other in the research. These research findings are similar to many studies (Elliott et al., 2001; Öner & Capraro, 2016; Pekbay, 2017). In this context, for example, Pekbay (2017) revealed that STEM activities generally increase student achievement, but do not have a significant effect on mathematics achievement, as a result of the study examining students' problem-solving skills and STEM interests. Again, Öner and Capraro (2016) revealed in their studies that the success and problem solving levels of students in the school who received STEM education and other students who did not receive this education were close to each other. Similarly, Elliott et al. (2001) revealed that the education received by university students participating in STEM education did not have a significant effect on their problem-solving skills. However, contrary to these findings, Roberts (2012) revealed that students develop their daily life problem solving skills by applying the rules, knowledge and skills they have learned in the fields of science, technology, mathematics and engineering so that they can solve problems related to daily life. Similarly, Öner and Yılmaz (2019) concluded that students with high problem-solving skills have positive views on STEM education.

In the context of the second sub-objective of the study, it was investigated whether the level of problem solving and gender interaction caused a significant difference in the STEM awareness levels of classroom teacher candidates. In this context, it was concluded that the STEM awareness total scores of classroom teacher candidates caused a significant difference in favor of female participants in the context of problem solving level and gender interaction. In the context of this result, it is seen that in some of the studies on STEM and problem solving, the views of women (Knezek et al., 2011; Cooper & Heaverlo, 2013; Modi et al., 2012; Knezek et al., 2013; Karakaya et al., 2018; Ertem et al., 2019) and in some of the men (Christensen et al., 2014; Öner et al., 2014) and in some, both samples have similar views (Buyruk & Korkmaz, 2016b; Karakaya & Avgin, 2016; Çevik, Danıştay & Yağcı, 2017; Haciomeroglu, 2017; Özdemir & Cappellaro, 2020).

In this context, for example, Cooper and Heaverlo (2013) concluded that the education given to female students on STEM increases their problem-solving skills. Again, Modi et al. (2012) also revealed that female students who are interested in STEM education also have high problem-solving skills. Similarly, Ertem Akbaş et al. (2019) also revealed in their study that secondary school students have a positive interest in STEM fields and that especially female students are more interested in mathematics than male students. However, contrary to the results of this study, Özdemir and Cappellaro (2020) concluded that the gender variable did not make a significant difference according to the STEM awareness levels of classroom teachers. On the other hand, Öner et al. (2014) concluded that the mathematics development of male students in STEM academies in different regions is higher than that of female students. As can be clearly seen from these findings, it can be said that gender and problem solving do not indicate a common result in raising awareness about STEM. Accordingly, it can be said that STEM awareness levels do not cause a significant difference in terms of problem solving level and gender interaction.

Conclusion and Recommendations

In conclusion; as a result of this study, which was conducted to examine the STEM awareness levels of classroom teacher candidates in terms of the gender variable of problem solving skills, it was revealed that the awareness of participants with different problem solving levels was similar to each other. In addition, it was concluded that female participants' awareness of STEM was higher than male participants in terms of gender and problem solving success. From this point of view, it can be suggested that studies should be carried out to increase the awareness of male students with different problem solving achievements towards STEM. Again, classroom teacher candidates should have positive views in order to enable them to gain problem-solving skills in their future professional lives and to understand their perspectives on science, technology and mathematics. In this context, it can be suggested to give importance to classroom practices that will positively affect their awareness of problem solving and STEM, and to organize the teaching environment in the teaching of courses such as mathematics teaching and science teaching, which are important factors in the learning of science and mathematics in the undergraduate education process of classroom teacher candidates. This study was limited only to classroom teacher candidates and was handled within the scope of problems that require four operation skills. In similar studies to be conducted, studies covering STEM awareness of science and mathematics teacher candidates can be conducted in the context of problems related to daily life. In addition, research can be conducted in experimental design by controlling the interaction of variables that may affect awareness skills for STEM.

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SECTION III - COMPONENTS RELATED TO STUDENTS' STEM LEARNING EXPERIENCES

Chapter 7 - The Relationship between Self-efficacy and Interest in a STEM Career: A Meta-Analysis

Katherine N. Vela , Sandra Miles

Chapter Highlights

- This chapter looks meta-analytically at education research published between 2014-2019. It includes 39 studies to determine the impact that various student factors (e.g., race, gender, participation in an intervention) have on an individual's self-efficacy toward science, technology, engineering, and mathematics (STEM) fields and to explore the relationship between self-efficacy and interest in STEM careers.
- Despite prior research that indicates race, gender, and participation in a STEM intervention influences students' self-efficacy toward STEM, the results from this meta-analysis indicate that race, gender, and participation in a STEM intervention did not have a statistically significant effect on individual STEM related self-efficacy.
- The results from this meta-analysis are consistent with previous research that shows a positive relationship between self-efficacy toward STEM and choosing a future STEM career.

Introduction

The past few decades have brought improvement to racial and gender equality in education, but when examined closely we continue to see racial and gender disparities in science, technology, engineering, and mathematics (STEM) fields. Though the percentage of women receiving bachelor's degrees now exceeds that of men, women receive less than 20% of engineering, physics, and computer science degrees (National Science Foundation & National Center for Science and Engineering Statistics, 2019). In addition to the gender imbalance, a racial discrepancy reveals itself among black and Hispanic Americans. In 2018, Black Americans received 10% of all bachelor's degrees awarded, but only 4-5% of the degrees earned in engineering, mathematics, or physics. Similarly, Hispanic students received 14% of bachelor's degrees awarded, but only 10-11% of those in the listed STEM fields. It is imperative to understand the reasons for this imbalance in STEM so that we can take steps to increase racial and gender diversity in STEM.

Albert Bandura posited that all behavioral change is driven by a combination of self-efficacy and outcome expectations, with self-efficacy being the stronger force (Bandura, 1977). Social Cognitive Career Theory (SCCT; Lent et al., 1994), an extension of Bandura's theory, suggests that self-efficacy has a strong impact on a student's career choice. Thus, in order to increase the number of women and underrepresented minorities in STEM careers, researchers need a better understanding of STEM self-efficacy to consider ways of making improvements. Although an abundance of research exists that examines the concept of self-efficacy, there is still much that is not understood. Many scholars have conducted research in an effort to validate Bandura's four sources of self-efficacy (mastery experiences, vicarious experience, verbal persuasions, and physiological/affective factors) and practitioners generally accept his three evaluation criteria (strength, generality, and level), but research has not yet explained how demographic factors contribute to the development of self-efficacy. Understanding the effect of demographic factors (such as race and gender) on self-efficacy may help explain the disparities that exist in STEM careers. Therefore, an essential research objective is to discover meta-analytically how self-efficacy differs in students based on their demographic characteristics, how participation in a STEM related intervention relates to an individual's STEM related self-efficacy, and how that self-efficacy impacts student choice of future careers.

Bandura's Theory of Behavior Change

There is a great deal of research that has been conducted in an effort to discover how student engagement and confidence can be changed in order to improve achievement. Bandura's (1977) theory of behavioral change claims that all behavior is driven by two sets of beliefs; outcome expectations and self-efficacy expectations. Outcome expectations refer to what an individual thinks will occur as a result of their actions while self-efficacy refers to an individual's belief that they can be successful at certain tasks. For an individual to engage and persist in any behavior, they will first make evaluations as to their ability to be successful at accomplishing the task, as well as the sort of outcomes they think are likely to occur (Bandura, 1977). Though both sets of beliefs are important, there is evidence that self-efficacy has a more powerful influence on achievement than outcome expectations (Shell et al., 1989).

Self-efficacy vs Self-concept

When looked at as a more general, domain specific construct, self-efficacy can become conflated with self-concept; therefore, it is important to define both terms within this study. Self-concept is a broad construct that refers to a person's perceptions about themselves. It is multidimensional and includes both cognitive and affective factors (Shavelson et al., 1976), while self-efficacy is a purely cognitive construct (Marsh et al., 2019). The main distinction between self-concept and self-efficacy is that self-concept inherently includes comparison with others. Specifically, with self-concept, individuals place themselves in a relative ranking with others to evaluate their abilities in a certain area (Bong & Clark, 1999). Self-efficacy, as Bandura presented the idea, is evaluated at a task specific level, and so an individual only considers their ability to complete the unique task. This added comparison component accounts for slight variations in measurements between self-efficacy and self-concept.

The distinction between self-efficacy and self-concept varies based on the level of generality being evaluated. Task specific self-efficacy has shown a stronger ability to predict achievement than self-concept (Bong & Clark, 1999). However, self-efficacy is most predictive when the self-efficacy instrument and the performance evaluation are administered within a small temporal window, and when the specificity between the two instruments closely matches (Choi, 2005). This seems to indicate that task specific self-efficacy is a better predictor of shorter-term outcomes like exam scores, but its predictive power decreases with long range outcomes. When both are viewed at a domain specific level, self-concept and self-efficacy appear to be equivalent measurements, though self-concept seems to be a better predictor of future grades than self-efficacy (Marsh et al., 2019). These findings illustrate the need to clearly identify the level of generality in a study, and also indicate a moderating role of self-comparison when evaluating long term self-beliefs.

Development of Self-efficacy

In his widely accepted theory, Bandura (1977) proposed four sources for the development of self-efficacy. The first source is *mastery experiences*. Bandura suggests that as an individual experiences repeated success with a given task, their confidence grows. Mastery experiences are generally accepted as the most influential source for self-efficacy (Usher & Pajares, 2009) and are separate, and independent, from cognitive ability (Pajares, 1996). The second source Bandura (1977) proposes is *vicarious experience*. As individuals observe others' successes or failures, they make judgements about their own abilities, based on self-comparisons. Usher (2009) found that students experienced stronger effects related to vicarious experience when they observed a peer, or someone close to their own age, than when they observed adults. Similarly, Schunk and colleagues (1987) noted that the perceived ability of a model needed to be approximately equal to, or a little above that of the observer to have a significant effect. Bandura's third source, *verbal feedback*, suggests that the comments of others can strengthen or weaken an individual's self-efficacy. This however, does not appear to have a consistent effect. Usher (2009) found that verbal feedback from teachers was more influential than that from parents and reasoned that this was due to the absence of pressure that comes along with parental expectations. However, other studies found that verbal persuasions from parents had a stronger effect on self-efficacy for black students (Garriott et al., 2014) suggesting that race or culture might affect how verbal persuasions influence self-efficacy. *Physiological and affective factors* can play a role in an individual's self-efficacy. Even if unrelated to the given task, feelings of being tired, angry, or anxious can affect an individual's self-beliefs about their abilities.

Variation in the Development of Self-efficacy

Self-efficacy does not develop the same way in all students, race and gender may moderate an individual's self-efficacy. For example, though mastery experiences are reported by men to be the most significant contributor to their self-efficacy, women and black students report stronger effects from vicarious experiences and verbal persuasions (Usher, 2009). Usher (2009) also found that women tend to attribute success to hard work or luck, while men typically attribute success to natural talent or skill. This gender-based distinction could explain the diminished effect of mastery experience in female students. Additionally, gender significantly contributes to self-efficacy even when Bandura's four sources are removed (i.e., mastery experiences, vicarious experience, verbal persuasions, and physiological/affective factors; Matsui et al., 1990). As mentioned previously, Garriott et al. (2014) found that black students were more influenced by verbal persuasions and vicarious experience than white students. Pajares and Kranzler (1995) found that black students show greater incongruence between their mathematical self-efficacy beliefs and their achievement. Specifically, black students tend to be overconfident in their abilities and anticipating higher performance than what they achieve (Pajares & Kranzler, 1995). These findings suggest a weaker influence of mastery experience on black students. It is possible that cultural differences and social inequities have contributed to the tendency of black students to see success in mathematics classrooms as distinct from mathematical ability. If black students view grades and exam scores as being highly related to cultural understanding of problem context, racial or cultural tensions between student and teacher, or access to additional resources, then mastery experience will not have as significant effect on their ability beliefs. Future research needs to further investigate the role that gender and race play in the development of STEM related self-efficacy. Paying attention to the differences in self-efficacy that exist as a result of these demographic characteristics can help us understand how to improve STEM related self-efficacy among different student subgroups and increase the racial and gender diversity in STEM careers.

Evaluating Self-efficacy

Self-efficacy describes an individual's confidence in their own abilities and is evaluated by reviewing three main factors. The three factors to consider when evaluating an individual's self-efficacy for a given task: *level*, *generality,* and *strength* (Bandura, 1997). *Level* is the perception of how difficult a task is. More difficult tasks tend to decrease a person's perceived self-efficacy. For example, Alias and Hafir (2009) found that when taking an exam, high school students who were told that the exam was written for college students performed worse and reported lower levels of self-efficacy than the students who were told that the exam was written for students at their level.

The second factor, *generality* deals with the specificity of the task. A person may have strong self-efficacy for spelling in general, but when faced with the task of spelling the word chrysanthemum, the individual may report a lower level of self-efficacy because they remember it as having been difficult in the past. Conversely, a person might have high self-efficacy for solving a particular math problem (e.g., 21+47) but low self-efficacy for math, or academics in general. In order to remove ambiguity in measurement and discussion, academic self-efficacy can be labeled as either task specific (Schunk, 1981), domain specific (Hackett & Betz, 1989), or general (Choi, 2004). Both task and domain specific self-efficacy are strongly correlated with positive educational outcomes and are important components of student success and interest.

The final factor that describes self-efficacy, *strength,* refers to how easily the perception of self-efficacy will change when faced with a challenge. Individuals with strong self-efficacy will persist in their beliefs while others will quickly change their beliefs when faced with disconfirming experiences. Though we understand that self-efficacy can vary based on the *level* of a task, *generality*, and *strength,* there is still much to learn about how these three components are themselves influenced. How do demographic, or environmental factors cause students to interpret these components differently?

Benefits of Self-efficacy

Whether examined on a task or domain level, self-efficacy correlates to many positive educational outcomes. First of all, there is a definite positive correlation between self-efficacy and academic performance (Pajares, 1996; Usher & Pajares, 2009). Researchers have found additional positive correlations between self-efficacy and motivation (Hackett & Betz, 1989), goal setting, decreased anxiety (Hackett & Betz, 1989), and persistence (Ferla et al., 2010). Higher levels of self-efficacy also relate to improved problem-solving performance (Pajares & Kranzler, 1995) and deeper learning (Ferla et al., 2010). Self-efficacy has been found to be a powerful component in the development of academic hope which is a key element in student motivation (Çam et al., 2020; Esmaeili et al., 2019). Though this is all correlational data, it speaks to the importance of further understanding and improving students' self-efficacy.

Self-Efficacy and Choosing a STEM Career

In addition to educational success, self-efficacy may contribute to future academic and occupational choices. SCCT (Lent et al., 1994) is an extension of Bandura's theory as applied to career choice. It claims that an individual's self-efficacy and outcome expectations contribute to interest in a particular subject, which then influences career choice. Several findings in the literature support this theory and allow us to understand the role of self-efficacy in choosing a career. Studies have found evidence that higher levels of self-efficacy contribute to a wider range of perceived career paths available (Lent et al., 1986) and that math related self-efficacy is a stronger predictor of future math-related career choices than past achievement (Hackett & Betz, 1989). The SCCT can be especially useful when trying to increase the number of women and underrepresented minorities in STEM fields. While the gender achievement gap in STEM fields seems to be closing, the gap in STEM related self-efficacy is not closing as quickly (Lloyd et al., 2005). Female students tend to underestimate their abilities in STEM related fields, though their performance is comparable to their male counterparts (MacPhee et al., 2013; Pajares, 1996). The SCCT suggests that we may be able to increase the number of women who enter STEM fields by finding ways to improve their self-efficacy for STEM subjects.

In order to investigate the effects that race and gender have in the development of STEM related self-efficacy, along with the potential effects of STEM related interventions, it is beneficial to look at self-efficacy in K-12 students (6 - 18-year-olds) for several reasons. First, students' self-efficacy beliefs change and develop as students proceed through school. Self-efficacy beliefs are generally more malleable in elementary school and similar for all students. However, as students enter middle school, slight gender based discrepancies begin to develop (Pajares, 2002), and self-efficacy fluctuates, at times, being out of alignment with their performance. By the time students leave high school their self-efficacy beliefs are more stable and correlate more strongly with their performance (Multon et al., 1991). Secondly, the beliefs students develop about themselves in public school have a strong influence on their future careers. Students' self-beliefs influence the classes they take in high school and their choice of major in college. Though some individuals wait to select a career, or switch careers later in life, the choices made during high school and college are very influential for a majority of students. Since these choices are strongly influenced by self-efficacy developed during the K-12 experience, it is important to direct our investigation of self-efficacy development to that time period.

The Need for a Meta-Analytic Review

A variety of studies have been done in an attempt to investigate, or validate, Bandura's sources of self-efficacy. However, there are still many questions to be answered concerning how STEM related self-efficacy is formed, and how its development is moderated by differences in gender, race, and participation in a STEM intervention. In a 1990 study that investigated Bandura's sources of self-efficacy on a sample of Japanese college students, only about 30% of the variation in self-efficacy was accounted for by Bandura's four sources (Matsui et al., 1990). A similar result was found in a more recent study of U.S. middle school students, with Bandura's four sources only accounting for 31% of the variation in science self-efficacy (Britner & Pajares, 2006). This supports the need for further investigation through meta-analysis to look for additional factors that contribute to the differences in self-efficacy among students, and how these differences may impact their future career choices.

Self-efficacy in STEM subjects is of special concern as the teaching and understanding of STEM becomes more essential in the modern world. Reviews of the literature are mostly narrative and reveal inconsistent findings, as well as a lack of research pertaining to STEM specific self-efficacy. The most recent meta-analysis on the topic (Byars-Winston et al., 2017) included 28 research reports that had been completed between 1977 and 2014. Their analysis revealed significant differences in the formation of self-efficacy between STEM and non-STEM fields, as well as different moderating effects of race and gender. However, because of the recent spotlight on STEM education to increase the number of skilled workers, there are many new publications that cover this topic and suggest the need for a new meta-analysis that will include a larger sample of more recent literature.

Method

The purpose of the current study is to look meta-analytically to determine differences in STEM related self-efficacy related to various student characteristics and interventions, and to explore the relationship between self-efficacy and interest in STEM careers. The following research questions were used to guide our meta-analysis:

(RQ1) What factors (e.g., race, gender, and participation in an intervention) impact an individual's self-efficacy toward STEM fields?

(RQ2) Does positive STEM self-efficacy lead to an interest in STEM careers?

Literature Search

The articles used in this study, were part of a larger content analysis which was conducted to make sense of the various definitions and surveys used to measure psychological dispositions (Vela, 2020). For the content analysis, search criteria were implemented in three main databases (ERIC, Educational Source, and PsychINFO) to systematically search for published articles that measured affect, attitude, perception, and self-efficacy within STEM educational research between 2014-2019. This timeline was appropriate because of the recent spotlight on increasing the number of skilled STEM workers by understanding STEM educational opportunities. The search from the content analysis resulted in a total of 315 included articles, 97 of which focused on some type of STEM related self-efficacy. The purpose of the content analysis was to review the definitional and measurement alignment surrounding the conceptual definitions of affect, attitude, perception, and self-efficacy within STEM educational research. For the purpose of this current study, we were only interested in the 97 studies that focused on STEM related self-efficacy and STEM education. For the purposes of this study, we examined any sort of self-efficacy related to a STEM field whether it was focused on a single subject (e.g. mathematics, engineering, science, computing, cyber security, circuitry, physics, or technology), or a composite measure (mathematics/science, or STEM). For the duration of this chapter the term self-efficacy will refer to STEM related self-efficacy as a whole, as measured by these various self-efficacy measures.

Inclusion and Exclusion Criteria

While these 97 studies met the criteria for the original content analysis, we screened the studies to ensure they met the added criteria needed for the meta-analysis: (1) experimental or quasi-experimental study, (2) provided measures of self-efficacy by various factors (RQ1) or measured the impact of self-efficacy on interest in STEM Careers (RQ2), (3) provided an effect size or data that could be used to calculate an effect size, and (4) involved students in grades K-12. A large number of studies were excluded because the studies were meta-analyses, qualitative, or because we were unable to calculate effect sizes. Figure 1 shows a flowchart diagram for the selection of studies for this meta-analysis.

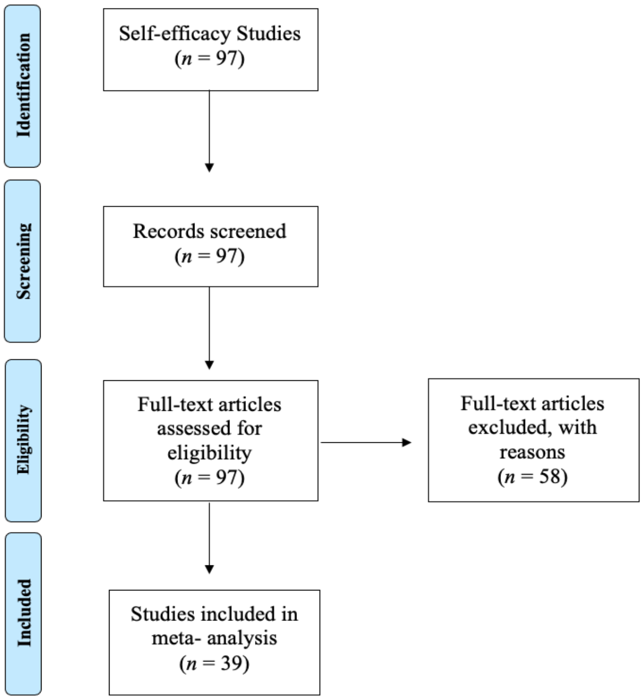

Figure 1. Flowchart for Selection of Studies in the Meta-analysis

For the first research question, we identified studies that reported various factors (e.g., race, gender, and participation in an intervention) that impacted students' self-efficacy. This first round of screening revealed a large variety in the type of factors measured, but since we were only interested in differences of race, gender, and participation in an intervention, the other studies were excluded. This resulted in the exclusion of studies that measured self-efficacy only in terms of Bandura's four sources of self-efficacy. There was great variety in the types of interventions included in our analysis. Some interventions took place outside the classroom in various workshops, camps, or after school programs while others were implemented in the classroom through various activities, computer programs, or curricular modifications. There were variations related to the level of active student participation in the intervention, the duration of the intervention, and whether students interacted with a scientist or other role model from the community. Since we do not intend to evaluate the effectiveness of a particular type of intervention, we did not excluded studies due to the variation in intervention category, but instead looked at student participation in any sort of intervention to see if there was a positive effect on self-efficacy.

For the second question, we included studies that used self-efficacy as the independent variable and interest in a STEM career as the dependent variable. Interest in a STEM career was reported in a variety of ways. We included studies where students self-reported their own interest in pursuing a certain STEM career as well as studies that reported whether or not a student enrolled in a STEM major in college. College major declaration usually indicates a desire to work in the declared field therefore these studies were included. We did not include studies that included interest in STEM *activities* as a dependent variable. Participation in a particular activity may indicate a momentary interest in the STEM field but it does not show interest for a career. Activity preferences may be made because students recall other activities that they have been assigned for that particular subject. For instance, students may indicate high levels of interest in building circuit boards when they view the alternative as drawing a diagram of a circuit, but interest may diminish when non-STEM activities are considered as options.

The included studies were all conducted using samples of students in K-12 schools, both in the United States and internationally. Since we wanted to study self-efficacy in K-12 students we excluded studies where the sample was adults, college students, or teachers. Some longitudinal studies (e.g., Sansone, 2017) were included where the initial phase of the study occurred while students were in K-12 schools, even if further phases occurred after graduation. Additionally, when a study included samples of both K-12 students and undergraduates (e.g., Barth et al., 2018) it was included only if the data from the K-12 sample could be extracted and analyzed independent of the adult sample.

Coding Procedures

Each of the 39 studies was coded independently. The following information was gathered on the coding form: citation, year, research question, factors (e.g., participation in an intervention, gender, race) independent variable, dependent variable, survey name, analysis used, and outcome measurement. Because many studies can include more than one analysis, one study could be coded multiple times as an individual study. We each coded independently with an overlap of ten studies and our inter-rater agreement for those ten studies was 90%. We discussed the coding to resolve disagreements which then resulted in 100% agreement. Each coded entry was then separated based on the research question (RQ1 or RQ2) and coded entries for RQ1 were further separated by factor (race, gender, and participation in an intervention). This resulted in 32 entries for RQ1_Race, 32 entries for RQ1_Sex, 35 entries for RQ1_Intervention, and 40 entries for RQ2.

Analysis

We conducted this meta-analysis in the following three steps:

(1) We computed Hedge's *g* effect size for each study.

(2) We calculated an overall effect size across the research studies for each question and/or factor.

(3) We performed the heterogeneity analysis.

Computing Hedge's g Effect Sizes

In order to be included studies had to provide one of the following types of outcome measurement: a) effect size with corresponding standard error, b) descriptive statistics (means and standard deviations), c) results from a *t*-test or one way ANOVA with group sizes, d) correlation coefficients with total sample size, e) standardized regression coefficients with total sample size, f) odds ratios with standard errors, or g) chi-squared values with total sample size. Table 1 presents the characteristics of the 39 studies included in this meta-analysis. The studies were published between 2014-2019.

Table 1. Studies İncluded in the Meta-analysis

Study #	Study	RQ	RQ1_Factor	Outcome Measurement
1	Alemdar et al. (2018)	1	Intervention	Regression
2	Almarode et al. (2014)	2		Logistic Regression
3	Amo et al. (2019)	1	Gender	Regression
			Intervention	Regression
4	Barth et al. (2018)	1	Gender	Descriptive Statistics
5	Blotnicky et al. (2018)	2		Chi-squared
6	Brown et al. (2016)	1	Gender	*t*-test
			Intervention	Descriptive Statistics
		2		Correlation, *F*-test
7	Bugallo et al. (2015)	1	Gender	*t*-test

8	Chumbley et al. (2015)	1	Gender	Descriptive Statistics
9	Covert et al. (2019)	1	Intervention	Descriptive Statistics
10	Dame & Westerlund (2015)	1	Intervention	Cohen's *d*
11	Daubenmire et al. (2017)	1	Intervention	Cohen's *d*
12	Denson (2017)	1	Race	Descriptive Statistics
			Intervention	*t*-test
13	Dubriwny et al. (2016)	1	Intervention	Descriptive Statistics
14	Falco & Summers (2017)	1	Intervention	Descriptive Statistics, *F*-test
15	Garriott et al. (2017)	2		Correlation
16	Gremillion et al. (2019)	1	Gender	Descriptive Statistics
			Race	Descriptive Statistics
17	Güdel et al. (2019)	2		Regression
18	Hiller &Kitsantas (2014)	1	Intervention	*t*-test
19	Kutnick et al. (2018a)	2		Correlation
20	Kutnick et al. (2018b)	1	Gender	*F*-test
			Intervention	*F*-test
		2		Correlation, Regression
21	LaForce et al. (2019)	1	Gender	Regression
			Race	Regression
22	Lee et al. (2015)	2		Logistic Regression
23	Leonard et al. (2016)	1	Intervention	Descriptive Statistics, *t*-test
24	Lindgren et al. (2016)	1	Intervention	Descriptive Statistics
25	Liu et al. (2014)	1	Intervention	Regression
		2		Regression
26	Martinez Ortiz et al. (2018)	1	Intervention	*t*-test
27	Mau & Li (2018)	2		Descriptive Statistics, Regression
28	Nix et al. (2015)	2		Logistic Regression
29	Nugent et al. (2019)	1	Gender	*t*-test
			Intervention	*t*-test
30	Riegle-Crumb et al. (2019)	1	Gender	Descriptive Statistics

			Race	Descriptive Statistics
31	Saleh & Hamed (2014)	1	Intervention	*t*-test
32	Sansone (2017)	1	Gender	Descriptive Statistics
33	Sasson (2019)	1	Gender	Descriptive Statistics
34	Star et al. (2014)	1	Intervention	Descriptive Statistics
35	Tellhed et al. (2017)	1	Gender	Descriptive Statistics
36	van Aalderen-Smeets et al. (2019)	2		Regression
37	Vongkulluksn et al. (2018)	1	Intervention	Correlation
38	Woods-McConney et al. (2014)	1	Gender	Descriptive Statistics
39	Zhou et al. (2017)	1	Intervention	Descriptive Statistics

We calculated effect sizes for each of the coded entries and converted them to Hedge's *g* using the package {esc} in RStudio 3.6.3 (2020). The code for most of the effect size conversions was taken from the online book *Doing Meta-analysis in R: A Hands-on Guide* (Harrer et al., 2021), but because some conversions were not addressed in Harrer's book, additional commands were taken from the official R website's instruction manual for the {esc} package (Lüdecke, 2019). This particular package was written for computing effect sizes specifically for meta-analysis. The methods used did not allow for the conversion of regression results because most of these studies did not provide individual group sizes for the treatment and control groups, or the standard deviation of the dependent variable, both of which are required for the R function. Due to the large number of studies that would have been excluded, we decided to incorporate one additional approach. We still excluded the regression studies that only reported unstandardized coefficients but retained those that reported standardized betas. Since the standardized beta is measured on the same scale as a Pearson *r* correlation coefficient, we were able to treat the standardized beta as a Pearson's *r* to allow the conversion. We converted the beta value to a Hedges *g*, since that conversion only required the full sample size. We attempted this same conversion with other online calculators to validate our method and received the same output values.

Overall Effect Size and Heterogeneity Analysis

We used the statistical software packages within RStudio to conduct the meta-analysis. We combined Hedge's *g* effect sizes to calculate an overall effect size. Researchers computed four overall effect sizes, one for each factor (race, gender, and participation in an intervention; RQ1) and one on the impact of self-efficacy on choosing a STEM career (RQ2). We calculated the *Q* statistics and used them to identify heterogeneity among the studies before creating forest plots to illustrate the relative strength of the independent variable to the dependent variable, and to help identify any considerable outliers (Moher et al., 2009). If the *Q*-test was statistically significant ($p < 0.05$), we considered the studies significantly comparable.

Results

(RQ1) What factors (e.g., race, gender, and participation in an intervention) impact an individual's self-efficacy toward STEM fields?

In order to examine how various factors may impact an individual's self-efficacy toward STEM fields, we calculated three overall effect sizes for the first research question, one for each factor of race, gender, and participation in an intervention.

Race

To determine how race might impact an individual's self-efficacy toward STEM fields, we calculated 32 individual effect sizes from 4 studies (see Table 2). Each effect size was calculated comparing the minority students to the white students. White students were chosen as the baseline group because they make up the majority of people in STEM fields.

Table 2. Identification of Included Studies for RQ1_Race

Study #	Study	# of Hedge's *g*
12	Denson (2017)	5
16	Gremillion et al. (2019)	3
21	LaForce et al. (2019)	20
30	Riegle-Crumb et al. (2019)	4
	Total	*32*

As shown in Figure 2, the overall effect size for how race impacts an individual's self-efficacy was not statistically significant (g = -0.41, CI= [-0.88; 0.06], p = 0.09) but had significant heterogeneity $Q(31)$ = 643.33 ($p < 0.05$), which indicates significant variability within the studies. According to the results in Figure 2, the first three effects sizes, the effect sizes from Study 12 (Denson, 2017), were determined to be considerable outliers. These three effect sizes were considerably smaller (g = -5.15; -4.68; -3.88), therefore they were removed and the overall effect size was calculated again. Figure 3 shows the results with the outliers removed. The revised overall effect size, with the outliers removed, was still not statistically significant (g = -0.04, CI= [-0.11; 0.02], p = 0.16), and continued with significant heterogeneity $Q(28)$ = 223.39 ($p < 0.05$). Removing the three outliers increased the overall effect size from -0.41 to -0.04, but still yielded an insignificant result.

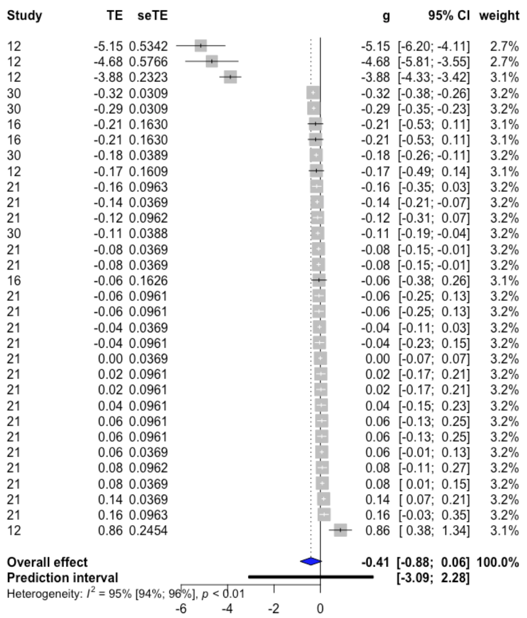

Figure 2. Forest Plot for Effect of Race

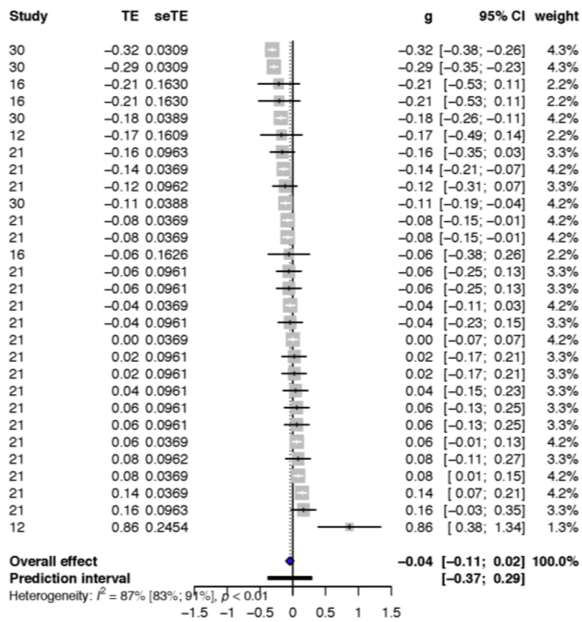

Figure 3. Forest Plot with Outliers Removed

Gender

Next, we were interested in how an individual's gender (male or female) might impact their self-efficacy toward STEM fields. We calculated 32 individual effect sizes across 14 studies (see Table 3). Each effect size was calculated comparing the female students to the male students. Male students were chosen as the baseline group because they are the majority in STEM fields. As shown in Figure 4, the overall effect size for how gender impacts an individual's self-efficacy was not statistically significant (g = -0.13, CI= [-0.26; 0.01], p = 0.06) but had significant heterogeneity $Q(31)$ = 455.87 ($p < 0.05$).

Table 3. Identification of Included Studies for RQ1_Sex

Study #	Study	# of Hedge's *g*
3	Amo et al. (2019)	1
4	Barth et al. (2018)	3
6	Brown et al. (2016)	1
7	Bugallo et al. (2015)	1
8	Chumbley et al. (2015)	1
16	Gremillion et al. (2019)	3
20	Kutnick et al. (2018b)	2
21	LaForce et al. (2019)	10
29	Nugent et al. (2019)	2
30	Riegle-Crumb et al. (2019)	2
32	Sansone (2017)	2
33	Sasson (2019)	1
35	Tellhed (2017)	1
38	Woods-McConney (2014)	2
	Total	*32*

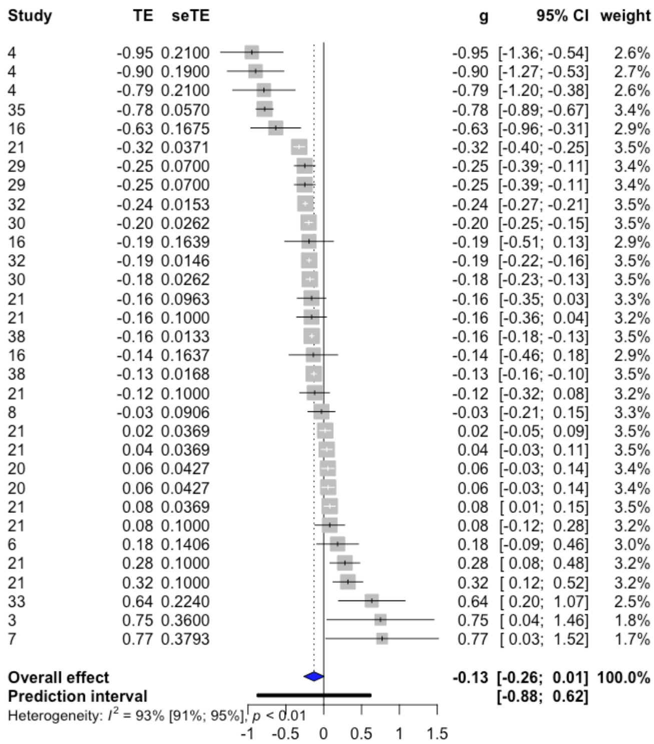

Figure 4. Forest Plot for Gender

Intervention

We next wanted to determine how participating in a STEM intervention might impact a student's self-efficacy toward STEM fields. Studies 10 and 11 provided a Cohen's *d* (Dame & Westerlund, 2015; Daubenmire et al., 2017) but because the standard error was not included, these two studies were excluded from the analysis. Therefore, there were 35 individual effect sizes calculated across 18 studies (see Table 4). As shown in Figure 5, the overall effect size for how participating in an intervention impacts an individual's self-efficacy was not statistically significant (g = 0.13, CI= [-0.15; 0.41], p = 0.35) but had significant heterogeneity $Q(34) = 512.53$ ($p < 0.05$).

Table 4. Identification of Included Studies for RQ1_Intervention

Study #	Study	# of Hedge's *g*
1	Alemdar et al. (2018)	1
3	Amo et al. (2019)	1
6	Brown et al. (2016)	1
9	Covert et al. (2019)	1
12	Denson (2017)	1
13	Dubriwny et al. (2016)	1
14	Falco & Summers (2017)	3
18	Hiller &Kitsantas (2014)	1
20	Kutnick et al. (2018b)	2
23	Leonard et al. (2016)	7
24	Lindgren et al. (2016)	1
25	Liu et al. (2014)	1
26	Martinez Ortiz et al. (2018)	1
29	Nugent et al. (2019)	3
31	Saleh & Hamed (2014)	2
34	Star et al. (2014)	1
37	Vongkulluksn et al. (2018)	3
39	Zhou et al. (2017)	4
	Total	*35*

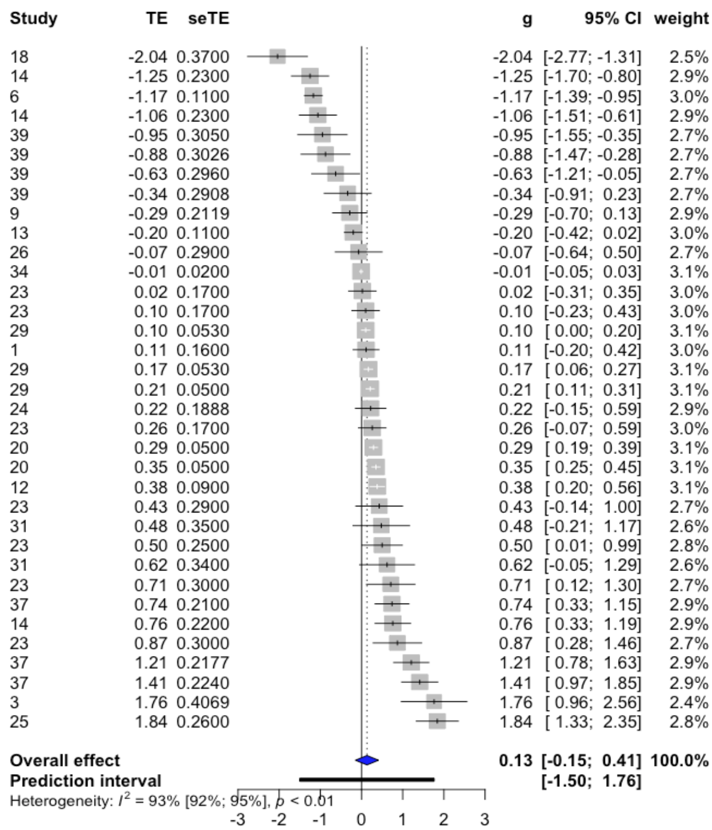

Figure 5. Forest Plot for Participating in an Intervention

(RQ2) Does positive self-efficacy lead to an interest in STEM careers?

For RQ2, we were interested in determining if positive self-efficacy in STEM fields leads to a positive interest in STEM careers. There were a total of 40 individual effect sizes across 12 studies (see Table 5). As shown in Figure 6, the overall effect size was not statistically significant (g = 1.32, CI= [-0.08; 2.72], p = 0.06) but had significant heterogeneity $Q(39)$ = 79,274.80 ($p < 0.05$). According to the results in Figure 6, the last two effects sizes, which came from Study 27 (Mau & Li, 2018), were determined to be extreme outliers. These two effect sizes were considerably larger than the others (g = 15.23; 23.93) and therefore removed, and the overall effect size calculated again.

Figure 7 shows the results with the outliers removed. The revised overall effect size, with the outliers removed, was statistically significant (g = 0.35, CI= [0.19; 0.51], $p < 0.05$), and had significant heterogeneity $Q(37)$ = 1,956.75 ($p < 0.05$). Removing the two outliers reduced the overall effect size from 1.32 to 0.35, but the revised overall effect size was statistically significant.

Table 5. Identification of Included Studies for RQ1_Intervention

Study #	Study	# of Hedge's *g*
2	Almarode et al. (2014)	16
5	Blotnicky et al. (2018)	1
6	Brown et al. (2016)	3
15	Garriott et al. (2017)	1
17	Güdel et al (2019)	1
19	Kutnick et al. (2018a)	1
20	Kutnick et al. (2018b)	3
22	Lee et al. (2015)	2
25	Liu et al. (2014)	1
27	Mau & Li (2018)	4
28	Nix et al. (2015)	6
36	van Aalderen-Smeets et al. (2019)	1
	Total	*40*

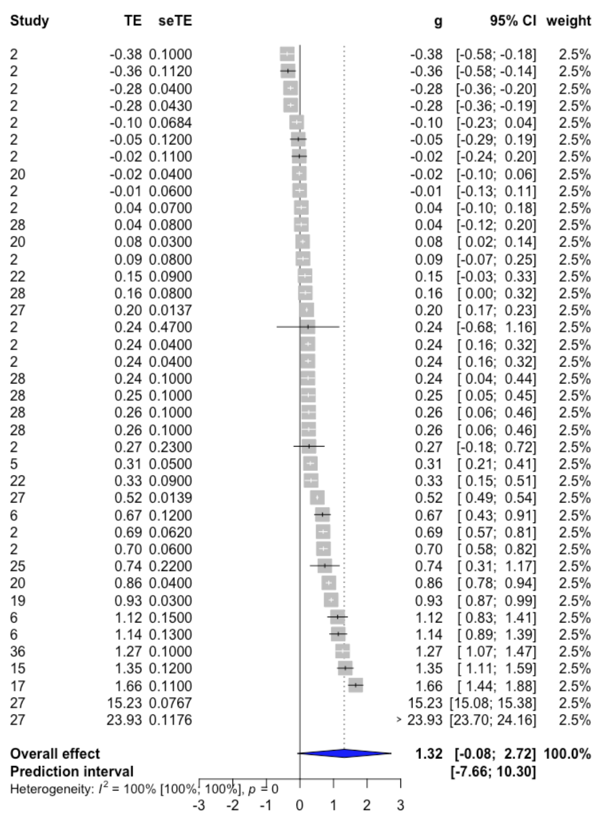

Figure 6. Forest Plot for Self-efficacy on Interest in STEM Careers

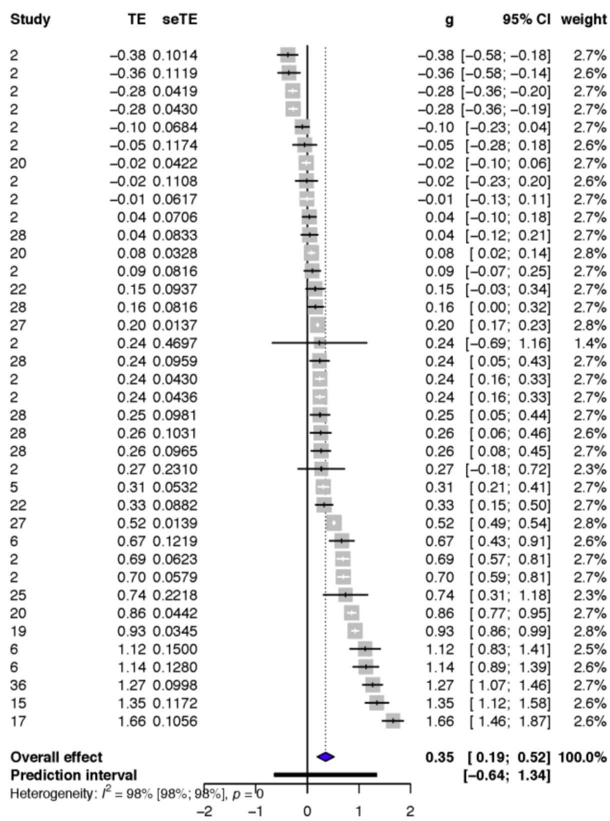

Figure 7. Forest Plot with Outliers Removed

Discussion

Currently there is an underrepresentation of women and minorities in STEM fields, with the majority of STEM professionals being white males. Therefore, it is important to determine if gender and race characteristics contribute to a difference in an individual's self-efficacy toward STEM fields. Prior research has shown that a student's self-efficacy, or confidence, toward a particular subject and their outcome expectations may impact their desire to pursue a career in that field in the future (Bandura, 1977, 1997). Furthermore, SCCT suggests that self-efficacy has a major impact on a student's choice in future careers (Lent et al., 1994) and therefore, understanding the factors meta-analytically, may be useful when trying to improve diversity in STEM fields. Therefore, we were interested in determining whether there are differences in self-efficacy related to various student characteristics (e.g., gender, race, and participation in an intervention) and in exploring the relationship between self-efficacy and interest in STEM careers over several years. Ultimately, we wanted to answer the following questions:

(RQ1) What factors (e.g., race, gender, and participation in an intervention) impact an individual's self-efficacy toward STEM fields?

(RQ2) Does positive self-efficacy lead to an interest in STEM careers?

To answer the first question (RQ1), we calculated three overall effect sizes, one for each of the following: (a) race (g = -0.04), (b) gender (g = -0.13), and (c) participation in an intervention (g = 0.13), none of which were statistically significant. The overall effect size for race and gender were negative, indicating that white students tended to have a higher self-efficacy when compared to their non-white peers and that male students tended to have a higher self-efficacy when compared to female students. While neither of these overall effect sizes were statistically significant, the results are in line with prior research that shows that white male students tend to be more confident in their abilities of STEM content (Zander et al., 2020). The overall effect size for participating in an intervention was positive, but not statistically significant. This positive effect size could indicate that interventions, such as STEM summer camps, role models, STEM activities implemented in classroom settings, and STEM simulations, could have a positive impact on improving student's self-efficacy toward STEM fields. Although race, gender, and participation in an intervention all had positive effects, it is surprising that none of these effect sizes were statistically significant, because prior research indicates there are significant differences in self-efficacy beliefs related to students' race and gender (c.f. Byars-Winston et al., 2017). The results from this meta-analysis indicate that there are not gender and racial disparities between students' self-efficacy, nor significant effects from participation in a STEM intervention. In other words, perhaps there are other factors (i.e., country, culture) that influence a student's confidence toward STEM fields, but more research into what these factors are and how they influence a student's self-efficacy may be required.

Finally, we were interested in determining the impact that self-efficacy toward STEM has on a student's desire to pursue a STEM career. The revised overall effect size, once the two outliers were removed, was statistically significant (g = 0.35). The results from this question demonstrate the relationship between positive self-efficacy and a positive interest in pursuing a STEM career, and align with prior research (Lent et al., 1986; 1994). This is an important finding, because it suggests that if we can ensure students are confident in their STEM abilities, they are more likely to pursue a career in STEM. Therefore, researchers and educators must look for ways to promote positive interactions with STEM curriculum and cultivate positive self-efficacy toward STEM.

Conclusion

In conclusion, these results provide generalizable information for educational researchers, policy makers, and educators by indicating that student characteristics, such as gender and race, and participation in STEM interventions do not significantly impact students' self-efficacy toward STEM fields. This suggests an improvement to the gender and racial gap in STEM, within the K-12 setting, in a broad sense and opens the door for more focused research. Future research should ask if gender or cultural differences affect a student's opportunities for mastery experiences. What types of mastery experiences are more influential in the development of self-efficacy, and how do those criteria differ by gender or race? Additionally, since the variation in the types of interventions included in our analysis were so different, future research should narrow the focus to determine whether some interventions are more effective than others, and if intervention efficacy varies for different student subgroups.

Further results from this study highlight the important role that self-efficacy toward STEM fields has on future desires to pursue STEM fields. This calls for educational researchers and educators to find innovative ways to cultivate positive self-efficacy toward STEM, so that students feel confident in their abilities and will be more likely to pursue these fields. Future research should determine if specific types of STEM-related self-efficacy (I.e., mathematics, computing, engineering) predict interest in a specific STEM career, or if improving students' general self-efficacy in mathematics or science will lead to the same interest in technical or computer related careers. Furthermore, because this meta-analysis was limited to K-12 settings, future research that focuses on undergraduate students' and adults' self-efficacy toward STEM fields is needed. As students leave K-12 settings, they can be impacted by life experiences or experiences in college that impact their desire to pursue a STEM field. This line of research will provide information about whether or not self-efficacy changes after K-12 settings and impacts one's desire to pursue a STEM pathway. Ultimately, educating a STEM-literate society and producing STEM-ready graduates, we will begin to fill the jobs available in STEM fields with a population that more represents our diverse society.

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Chapter 8 - Students' Awareness, Perceived Ability, Value, and Commitment to Science and Mathematics: A Perspective from High School Students in Brazil

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Chapter Highlights

- This study adds to the literature on STEM identity by reconceptualizing a quantitative instrument to examine aspects of two different identity frameworks.
- We conducted this study to inquire and answer this research question: *What are Brazilian high school students' awareness, perceived ability, value, and commitment to science and mathematics?*
- Our results suggest that students are more aware of science than mathematics and that while they prefer science over mathematics, not many students indicated that they enjoyed taking these courses.
- Additionally, we found that, in terms of students' perceived ability, more students found mathematics to be challenging than science.
- Despite the general lack of perceived ability of the students in mathematics and science shown by our results, we found that most students valued both mathematics and science.
- Surprisingly, our study revealed no gender differences in STEM identity between male and female students.

Introduction

The The next generation of skilled workers require knowledge sets and abilities (e.g., scientific habits of mind, mathematical and technological literacies, engineering design practices) to effectively function in society (National Academy of Sciences et al., 2007). Some countries are investing in their science, technology, engineering, and mathematics (STEM) in formal and out of school settings, which in turn positively influences students' values, perceived ability, and motivation to learn STEM subjects (Organisation for Economic Cooperation and Development [OECD], 2021). Student interest in pursuing careers in STEM disciplines has decreased in developed countries like Australia, while it increased in developing countries like India and Malaysia (Thomas & Watters, 2015).. Several contributing factors in varying student interest in STEM careers included national priorities, educational practices and teacher beliefs, family values, and societal influence (e.g., social media, known personalities from televisions/Internet). For instance, the active learning approaches of teaching science through Malaysian culture and language contributed to positive changes in student interest in STEM disciplines. In another example, Indian national education priorities in STEM programs is a major contributor to economic growth and in developing general citizenry competence (Thomas & Watters, 2015).

The study of Stolk et al. (2018) observed how teachers' pedagogical approaches could influence students' motivation to study STEM subjects. They found that students engaged in project-based, and discussion-based courses exhibited a deeper, more intrinsic motivation than undergraduate students participating in STEM courses using more traditional teaching strategies, such as lecture. Additionally, Stolk et al. found that, with respect to gender, male and female students expressed similarly high motivations in courses employing project-based and discussion-based teaching strategies. At the same time, there were greater differences in male and female student motivation in courses that used more traditional teaching strategies. According to Stolk et al., these traditional teaching strategies tend to increase and/or perpetuate the gender gap in STEM due to their tendency to "thwart learners' basic needs," thereby "[leading] to controlled motivations and less desirable outcomes" (p. 4). This suggests both that traditional teaching strategies may play a significant role in perpetuating the gender gap in STEM disciplines, and that newer, non-traditional teaching methods such as project-based and discussion-based teaching and learning can curb this gender gap. These traditional teaching strategies have the potential to reinforce the "gender-role stereotypes and gendered socialization processes in traditionally male dominated domains such as mathematics and engineering" (p. 6). For example, Otaviano et al. (2012) note that traditional teaching strategies can suppress student interest and motivation in STEM disciplines. For example, this may occur when a teacher writes information they consider to be valuable on the board at the front of the classroom, and students then dutifully copy it down into their notes, followed by repetitive exercises based on the teachers' presentation. This can be especially damaging for female students who already receive gendered messaging regarding whether or not they belong in STEM fields (Stolk et al., 2018). Moreover, according to Teixeira (2019), traditional science teaching methods that are more teacher-centered have been critiqued heavily in Brazilian education, and current research on teaching and learning places emphasis on critical thinking skills, scientific literacy, and taking a more student-centered pedagogical approach. Similarly, Otaviano et al. found a relationship between motivation, creativity, and academic achievement in mathematics for Brazilian high school students. Their findings suggest that teaching practices that promote creativity among students may lead to an increase in their motivation, and subsequently their academic success.

Some research studies saw students' gender as a factor in selecting STEM careers. According to Sadler et al. (2012), STEM career interest is stable and high for male students in high school, but it declines overtime for female students. They saw female students are likely to find health and medicine-related careers more attractive as compared to males who found other STEM fields more attractive. The authors write, "By far the most dominant factor influencing engineering or science career interest at the end of high school is student interest at the start of high school, a factor that differs greatly by gender" (p. 422). Moreover, Shimada and Melo-Silva (2013) found that female adolescent and young adult students exhibited preferences for helping professions in line with gender stereotypes when making career choices. They recommend that schools take an active role in facilitating the deconstruction of gender stereotypes by cultivating environments where students can feel psychologically and emotionally safe in reflecting on gender issues as they relate to vocations.

Negative gender stereotypes in STEM can also be perpetuated by parents, family members, and teachers (Ertl, et al., 2017; Shapiro & Williams, 2012; Tiedemann, 2000). Ertl et al. (2017) note that gender stereotyping can begin with parents, who may "regard daughters as being less talented in mathematics and science" (p. 3). This can be harmful because such negative stereotypes can undermine the performance of STEM-related tasks (Shapiro & Williams, 2012). Shapiro and Williams (2012) refer to this phenomenon as a *stereotype threat*. In addition to being perpetuated by parents and families, gender stereotyping can be promoted by teachers, particularly in early elementary grades, which can have a damaging effect on students' perceived ability in STEM (Ertl et al., 2017). For example, Tiedemann (2000) found that third and fourth-grade teachers in Germany perceived male students to have more mathematics ability than their female counterparts, despite the fact that male and female students in the study performed at the same level. These perceptions were also internalized by the parents, further perpetuating gender stereotypes.

In addition to teachers' self-efficacy and pedagogical practices, families of students can also influence students' motivation and perception toward the development of their STEM identity. Archer and colleagues (2012) suggest a pivotal age of 10-14-years when science aspirations are formed in children. "Science identity is the sense of who students are, what they believe they are capable of, and what they want to do and become in regard to science" (Aschbacher et al., 2010, p. 566). Archer et al. (2012) write that parental attitudes towards science have a large impact on the "children's science aspirations" (p. 888) through encouragement or practice of science in daily life. The authors note White and South Asian middle-class parents make science familiar and desirable by devoting time and resources to cultivate the children's science interests. Moreover, Godwin and colleagues(2020) outline the need for further research into STEM identity, including quantitative research that could "capture changes in students' identity over shorter periods" (p. 273) and that considers multiple factors such as psycho-social processes, learning and socialization, and equity issues simultaneously. Aschbacher et al. (2010) explored how 33 high school students developed their science identities. They found that students' microclimates, which they define as "a combination of communities of practice at home, at school, and outside of school" (p. 578), appeared to impact the students' science identities, and that "students expressed positive attitudes toward science and non-science pursuits where they experienced success and received support from important people in their lives" (p. 564). Aschbacher et al. (2010) argue that these findings support the importance of communities of practice in developing students' science identities. Furthermore, Collins and Jones Roberson (2020) investigated how Black male students in a gifted high school mathematics program developed and expressed their STEM identities. They found that "STEM identity is connected to intense interest in practical problem-solving," "parents' engagement influences STEM identity development," "a pronounced social, emotional, and cultural context effects STEM development," "strong motivation leads to success," and "magnet school culture influences and fosters confidence in STEM skills" (p. 222).

Within the existing research base on STEM identity, there are several gaps in the literature. Hannula and colleagues (2016), in considering the state of research on identity in mathematics education note the need for a bigger focus on interviews instead of classroom interactions. In addition, they highlighted gaps in the existing literature on STEM identity in terms of small sample sizes, connecting identity to other affective measures, and the lack of quantitative instruments to measure short-term changes in identity. According to Rahm (2008), most approaches to developing STEM identity assume that such development is a natural process. Paul et al. (2020) articulate a need for research that considers measures of identity measures "across diverse student populations" (p. 15). Mahoney (2010) recommends follow-up interviews after the initial response on a questionnaire, using the assessment at multiple points in time to conduct a longitudinal analysis, applying the instrument to larger, diverse populations, and looking at the ways in which the different aspects of the framework (value, perceived ability, commitment, and awareness) interact. Hazari et al. (2010) indicate the need for more qualitative research to follow up quantitative understandings of STEM identity to better understand specific instructional approaches that can develop students' STEM identities. Our study, seeks to fill some of these gaps in the literature in the following ways: using a larger sample size and connecting identity to other affective measures (Hannula et al., 2016), including diverse populations in our STEM identity research (Paul et al., 2020; Mahoney, 2010), and incorporating follow-up interviews after our initial survey responses (Mahoney, 2010).

In order to address some of the gaps mentioned, we conducted this study to inquire and answer this research question: *What are Brazilian high school students' awareness, perceived ability, value, and commitment to science and mathematics?*

Literature Review

Conceptual Framework

STEM identity, much like the construct of identity in general, has been conceptualized and reconceptualized in the literature in a variety of ways (Carlone & Johnson, 2007; Collins & Jones Roberson, 2020; Godwin et al., 2020; Hazari et al., 2010; Paul et al., 2020; Sadler et al., 2012; Vincent-Ruz & Schunn, 2018). According to Godwin et al. (2020), "identity is a core aspect of individuals that informs their internal states as well as actions in the world, and as a result, it has significant explanatory power in understanding multiple aspects of individual experience in STEM" (p. 267). Godwin et al.(2020) caution against considering STEM identity a singular construct, as there are in fact a plurality of STEM identities mediated by individual contexts. For example, Godwin et al. explain that STEM identity can be considered at different levels, such as the individual, person-centered level, the meso level, which includes the person and their immediate surroundings (e.g., the classroom), and also at the level of timescale, at which a students' STEM identity may (or may not) change over time. Moreover, Collins and Jones Roberson (2020) define STEM identity to be "the way individuals view themselves based on a belief in their ability to utilize STEM skills and/or to become a STEM innovator or professional" (p. 218). Kim et al. (2018) argued that STEM identity is a form of social identity in which "individuals see themselves in terms of their membership in a social group." Moreover, being part of a group has two aspects, such as a psychological sense of belonging and social acceptance or individual recognition by the group. Although STEM identity is sometimes considered as an integrated concept, it has also been thought of as siloed science, technology, engineering, and/or mathematics identities.

Paul et al. (2020) describe three different models of science identity prevalent in the literature. The first model describes "one's science identity [as] a singular construct that consists of self-recognition and recognition by others as a science person." (Paul et al., 2020, p. 2). This model of science identity involves an individual's understanding of how they fit into the realm of "science" based on their own self-conceptualization in terms of interest, perceived ability, value, and commitment, as well as others' understanding of them. Embedded in this "recognition by others" is also how others perceive a person in terms of their own language, culture, rules, etc. According to Vincent-Ruz and Schunn (2018), this type of science identity "is psychometrically distinct from the other science attitudinal measures often attributed to identity" (p. 6). Vincent-Ruz and Schunn found that these two separate components of science identity ("perceived personal science identity" and "perceived recognized science identity") can be interpreted in a coherent manner that describes an overarching science identity that can be an important factor for students in deciding whether or not to pursue science outside of school. In particular, science identity was found to be a greater predictor for such choices in female students compared to male students. In addition, female students, on average, had weaker science identities than their male counterparts. They, therefore, concluded that the development of a solid science identity for girls between the ages of 13-16 was important in closing the gender gap in science.

The second model of science identity focuses on a collective identity as an outcome of other attitudes and values a person might have, as well as their expectation of success in science, and how an individual's identity emerges in ways that differentiate themselves from the collective (Paul et al., 2020). According to Eccles (2009), this model of identity encompasses two categories of self-perceptions: "(a) perceptions related to skills, characteristics, and competencies…and (b) perceptions related to personal values and goals" (p. 78). While this model of science identity can provide a basis for predicting one's choices in relation to science based on their identity, it is unclear whether science identity, in this manner, exists separately from other attitudinal constructs such as motivation and interest in science (Vincent-Ruz & Schunn, 2018). Aschbacher et al. (2010) studied science identities (model 2) of high school students in relation to the ways in which their interest in science, engineering, and medicine evolved over time. They found that students' science identities were influenced by their home environment, particularly whether their family had the resources to intentionally expose the student to scientific contexts, concepts, and ideas.

Paul et al.'s (2020) third model of science identity is based on the work of Carlone and Johnson (2007) and Hazari et al. (2010). This third model extends the first model Paul et al. describe. According to Carlone and Johnson, a person's science identity lies at the intersection of their performance, competence, and recognition. Recognition here is meant in the same way described in Paul et al.'s (2020) first model, while performance is essentially a public exhibition of the trappings associated with science such as "ways of talking and using tools" (Carlone & Johnson, 2007, p. 1191), and competence is the degree to which one demonstrates their "knowledge and understanding of science content [although this] may be less publicly visible than performance" (Carlone & Johnson, 2007, p. 1191). Hazari et al. (2010) added to this model of identity by including a fourth component, interest, to the science identity framework, and emphasizing that this type of science identity intersects both with a student's personal identity as well as their social identity. This is significant because one's interest in science (or any disciplines) is strongly correlated with their determination to pursue (and persist in) schooling and careers in science (Paul et al., 2020). Using this model in a mathematics context, Cribbs et al. (2015) found that, for a nationally representative sample of students in the United States, competence/performance did not have as much of an impact on mathematics identity as compared to interest and especially recognition, which both appeared to be more strongly connected to identity composition. Godwin (2016) also adapted this model of identity to describe engineering identity for undergraduate engineering students, and found it offered a valid measure of students' engineering identities. Hazari et al. (2017) point out that, within this model, recognition by students' high school physics teachers may be one of the most impactful sources of recognition for developing and sustaining a physics identity for female undergraduate physics students.

Our study seeks to understand students' attitudes toward science and mathematics, anchored in a combination of the second and third models of identity outlined above. Students who exhibit a strong STEM identity may be more motivated to pursue STEM majors and careers upon completion of high school (Wentzel, 1998). Teacher pedagogical practices in K-12 schooling can have the effect of either strengthening or weakening students' STEM identities and motivation (Archer et al., 2012; Stolk et al. 2018). Additionally, Stolk et al. (2018) found that teachers' pedagogical practices can have the effect of closing the gap between male and female students' motivation and interest in STEM. This suggests that, through their pedagogical practices, teachers can be influential in cultivating the STEM identities of all students. We adapted Mahoney's (2010) measure of students' attitudes toward STEM in terms of their awareness, value, perceived ability, and commitment. These attitudinal aspects relate to students' initial and long-term interest, competence, performance, and perceptions of values and goals. Although Hazari et al. (2010) note the importance of interest in the formation of students' STEM identity, it is considered as one construct, while Mahoney's (2010) conceptualization breaks identity up into both initial and long-term, which we feel is important for a more comprehensive understanding of students' interest in STEM.

Additionally, using Mahoney's framework, we are able to blend the model of STEM identity put forth by Hazari with that of Eccles (2009), which incorporates students' self-perceptions as they relate to their own values and goals. In our case, we are using Mahoney's instrument to measure the extent to which science and mathematics are valued by Brazilian high school students. In this way, our study adds to the literature of STEM identity by merging two more distinct identity conceptualizations.

Values, Perceived Ability, and Motivation in Learning STEM Disciplines

When students develop an intrinsic motivation in STEM, this can lead to the development and strengthening of students' STEM identities (Stolk et al., 2018). Stolk et al. (2018) describe intrinsic motivation as "deeply internalized engagement based on interest, enjoyment, satisfaction, or passion in an activity" (p. 3). In our study, we relate this to students' awareness, perceived ability, value, and commitment in science and mathematics. Mahoney (2010) conceptualizes the terms awareness, perceived ability, value, and commitment as they relate to the STEM attitudes of high school students. According to Mahoney, students' awareness of STEM is essentially their initial interest in a given STEM discipline and describes the degree to which students are knowledgeable about a given discipline both in general and with respect to related course offerings at their school. Commitment is similar to awareness in that it represents a students' long-term, as opposed to short-term, interest in a STEM discipline, and relates to their interest in pursuing careers and activities involving that STEM discipline in the future (Mahoney, 2010). Some researchers have documented how extra-curricular and informal STEM programs have influenced students' interest and awareness in STEM. For example, Foud (1995) investigated how a year-long intervention program promoted middle-school students' academic achievement and career awareness in science and mathematics. Foud found that the program was effective for all students, including students traditionally underrepresented in STEM: students in the program, which promoted career awareness in science and mathematics, performed better in both disciplines than students who did not participate in the program.

Perceived ability is a students' own belief in their capacity for success in a given STEM discipline both in general and in terms of school subjects (Mahoney, 2010), and is similar to how other researchers have conceptualized students' competence and performance in STEM identity researchers (e.g., Carlone & Johnson, 2007; Hazari et al., 2010; Paul et al., 2020). In analyzing the relative impacts of different facets of students' STEM identity, Cribbs et al. (2015) found that, for a nationally representative sample of students in the United States, competence/performance did not have as much of an impact on mathematics identity as compared to interest and especially recognition, which both appeared to be more strongly connected to identity composition. Goff and colleagues (2020) explored the ways in which participation in an informal STEM program contributed to students' STEM identity development and found that students who participated in informal mathematics and science environments expressed greater levels of perceived ability than students who did not participate in these informal learning environments. Additionally, Goff et al.found that male students perceived higher levels of competence in mathematics and science than female students.

Value refers to the importance students place on a STEM discipline, both for society and for their own learning and understanding (Mahoney, 2010). As such, the ways in which students value STEM disciplines can be important to students' academic achievement in STEM. For example, Topçu et al. (2016) found that students in Turkey and Korea who valued science and mathematics were significantly more likely to perform well in those disciplines. When they analyzed students' value of both mathematics and science separately, they found that students had similar levels of perceived value in both disciplines.

Strong motivation in STEM can coincide with the development of a strong STEM identity for students. For example, Starr and colleagues (2020) examined the ways in which undergraduate students' STEM identities and motivations changed over the course of an introductory biology course while engaging in authentic science practices. These science practices included hypothesis development and evaluation and the use of evidence to support scientific claims. They found that student engagement in authentic science practices was an important factor in strengthening students' motivation and identity in STEM, as well as raising students' academic achievement in STEM subjects. Additionally, Starr and colleagues' findings suggest that both participation in authentic science practices and classroom environments that foster students' felt recognition as scientists may be even more important for students who are traditionally underrepresented in STEM fields. Similarly, Collins & Jones Roberson (2020) found that motivation in STEM and the development of a STEM identity were both important factors in the success of gifted Black male students in a magnet high school program. In particular, they found that parental engagement, as well as social, emotional, and cultural contexts, were important for developing students' STEM identities, sparking and sustaining their interest and passion in STEM. It is important to note, however, that such factors are not always comparable among the constituent STEM disciplines. For example, Rice et al. (2013) found that students received higher levels of parental support for mathematics than for science.

There are various instruments used to measure students' motivation, attitude, and interest in

STEM disciplines. For example, Paul et al. (2020) developed instruments for measuring elementary school students' STEM and engineering identities. Their instruments contained measures for aspects of identity such as competence, interest, self-recognition, and recognition by others. These instruments were surveys to measure the degree to which students agreed with various statements representing each of these aspects of identity and were adapted from similar instruments used to measure STEM identity in older students (i.e., middle and high school). For example, to measure competence, they used items such as "I am able to do well in activities that involve STEM" (p. 11). Interest was gauged by items such as "I enjoy learning about STEM!" (p. 11). Finally, self-recognition was measured through items like "I see myself as a STEM person," and recognition by others through items such as "My best friends see me as a STEM person" (p. 11). While they did include measures for perceived ability (competence) and awareness/commitment (interest) their instruments did not include measures for value. Paul et al. found that the instruments they developed were age-appropriate for the fourth-grade elementary student population they studied. Dou et al. (2019) looked at the ways in which students' STEM identity related to their "STEM career intention later in life" (p. 623). Specifically, in terms of STEM identity, they measured interest and recognition using a Likert scale in which participants indicated the degree to which they agreed or disagreed with various statements.

Dou et al. (2019) measured interest with items such as "Topics in STEM excite my curiosity" and recognition through items including "Others ask me for help in STEM" (p. 629). Similar to our study, Dou et al. did include value (interest) in their measurement of STEM identity, but they did not include measures for ability, awareness, or commitment. In their study of the STEM identity of college freshman, Dou et al. found a strong, positive relationship between students who had highly developed STEM identities and their propensity to pursue a STEM career. Further, Dou et al. found that childhood experiences such as "talking with friends or family about science, as well as reading or watching fiction and nonfiction science media, had significant-positive influences on students' STEM identity" (p. 632).

Mahoney (2010) developed and validated an instrument to quantitatively measure the STEM attitudes of high school students in grades 9-12. Their instrument was designed to measure students' awareness (initial interest), perceived ability, value, and commitment (long-term interest) in each of the constituent STEM disciplines through the use of a 34 item-questionnaire aligned to a Likert scale, which was focused into a 24-item questionnaire based on the results of a pilot study. Ultimately, Mahoney found that "STEM-based high school students did not exhibit a statistically significant more positive attitude toward the content areas of STEM when compared to the college-preparatory high school students" (p. 30). They also found that, with regard to gender, there were no significant differences between the STEM attitudes of the male and female students. While this study accounted for various affective measures of STEM attitude, Mahoney did not use the instrument to describe STEM identity as we do here.

Why is STEM Identity Important?

Identity as a construct can provide a useful lens for analyzing the successes and experiences of members of marginalized groups in STEM (Carlone & Johnson, 2007). The study of Sadler et al. (2012) showed how science identity changes based on gender throughout high school. For instance, by the end of high school, female students are more likely to find value in health and medicine careers compared to male students who find engineering and computer science more valuable. According to authors, Sadler et al. (2012), the experiences in science courses may be different for male and female students as teaching methods used by teachers could target male students favorably, there may be little or less welcoming STEM related activity opportunities for female compared to male students, and external environment (e.g. social media, acquaintances outside of school) could also directly or indirectly influence student experiences. According to Ceci & Williams (2010), when looking at male and female students who are good at math, the female students are also more likely to have good verbal skills, opening more career opportunities such as medicine, etc., for them (p. 278). Moreover, STEM identity can influence the motivation and attitudes of students toward learning STEM subjects. These motivations and attitudes can be an important factor in students' academic achievement. For example, Ajisuksmo & Saputri (2017) found that Indonesian high school students' attitudes toward mathematics were predictive of their academic achievement in mathematics.

Cook and Artino (2016) define motivation as "the process whereby goal-directed activities are initiated and sustained" (p. 997). According to Archer et al. (2012), the three biggest factors affecting a student's science aspiration are the parent's STEM attitudes (family attitude of engaging and encouraging science in everyday life or not), student's science self-concept and school science experience. Their findings showed that middle class families naturally gravitated towards science, and were able to devote resources and time to carefully and purposefully nurture their children's science interests, while the working class families were not that familiar with science ("science was peripheral to parents' and children's everyday lives" (p. 903)) did not have economic, or sociocultural resources at their disposal to nurture their children's science aspirations.

Aschbacher et al. (2010) found that strong STEM interest in most students develops prior to 10th grade. The authors note that many parents and students do not have an adequate understanding of the math and science requirements embedded in many jobs and hence regard them as unimportant to their aspirations or interests. According to Aschbacher et al., the family's socioeconomic status also impacts STEM persistence (parents from middle and upper class families are able to devote resources to support their children's STEM interests) and are more likely to be familiar with science and STEM careers. Many of the students reported poor school science experiences, desired STEM courses not offered, noted negative experiences of students when seeking help from their STEM teachers, and indicated that science learning was not a priority. Moreover, students reported negative interactions with their school counselors pointing to science and mathematics courses being viewed as challenging and as only for certain people, along with little to no parental support leading to waning STEM interests. According to Wentzel (1998), parental, teacher, and peer support have an additive effect on motivational and academic outcomes (p. 207). As an example of a primary additive effect, "perceived support from parents was the only type of support that predicted students' academic orientations" (p. 207). Perceived support from teachers is related to interest in class and compliance with class rules and expectations and perceived support from peers helps conform to acceptable school behavior and higher school motivation. Wentzel (1997) linked perceived teacher and peer support to social goal achievement (p. 411).

Wang (2013) notes that prior exposure to science and math courses, student achievement in these science courses, and self-efficacy beliefs of the student to succeed in the STEM courses helps solidify their intent to major in STEM. Additionally, a student's intent to graduate from a STEM major is strongly related to their STEM (math) self-efficacy belief (Wang, 2013). The author also notes that even when the STEM course achievement is the same, male students report higher self-efficacy than female students. According to Hidi & Renninger (2006), a person's interest is an important motivational condition for learning as it influences "attention, goals and levels of learning" (p. 111), and interests can be developed. Deci and colleagues (1991) note that engaged students "value learning, achievement, and accomplishment" (p. 338) even on activities and subject matter that is not of interest to them. The authors note that people are more willing to perform an activity then it has a personal value and usefulness.

Method

Research Design

This study employed a mixed research method, involving the collection and analysis of both quantitative and qualitative data (Creswell et al., 2011) to answer our research question: *What are Brazilian high school students' awareness, perceived ability, value, and commitment to science and mathematics?* The quantitative research is concerned with the systematic investigation of social phenomena, using statistical or numeral data (Watson, 2015). A survey developed by Mahoney (2010) was used in order to gather and analyze 291 high school students' awareness, perceived ability, value, and commitment toward science and mathematics disciplines inside and outside of school contexts. At the same time, a qualitative method allows us to focus on the meaning of human experiences for the purpose of providing detailed information about setting and context, emphasizing the voices of participants through quotes (Creswell et al., 2011). In this study, semi-structured interviews were conducted with 12 high school students from the total sample. We describe our research context, participants, instrument, and analysis in the following sections.

Educational and School Context

Our research was conducted in the city of Taubaté in São Paulo, Brazil, which is located about 130 km from the capital and business center. Taubaté is home to about 300,000 residents and is ranked tenth among the most populous municipalities in the state. The education system in Brazil is organized in three levels: pre-school education for children 6 years old and younger, basic education for those between the ages of 6 and 17 years; and higher education for those students beyond 17 years old. Basic education in elementary school is mandatory for children ages 6 to 14 with nine years of schoolwork, followed by three years of study in a high school. The high school curriculum consists of the following subject areas: Languages (Portuguese and Literature, Arts, Physical Education), Mathematics and Natural Sciences (Physics, Chemistry, Biology), Human Sciences (History, Geography, Philosophy and Sociology), and a Foreign Language (English). High school education is provided by the different levels of government: municipal, state, and federal. It is worth noting that our study was conducted with students from five municipal high schools in the city of Taubaté.

High school students in Taubaté are provided two schedules: during the day from 7:30 am to 11:30 or in the evening from 18:30 to 22:30, which results in a total of 3,240 contact hours of classes in three years. Students take four hours of mathematics per week for forty weeks per year, which is a total of 480 hours in three years. They also take courses in natural sciences for a total of 880 hours over the course of three years. Table 1 shows the distribution of contact hours per subject areas:

Table1. Unified Curricular Matrix for Municipal High Schools in Taubaté

Secretary of Education of Taubaté (São Paulo) – High School **Period: day/night** **Duration of course: 3 years/ 40 weeks/200 school days** **Duration of classes: 50 minutes**					
Disciplines		**2019/1st.grade Number of classes per week**	**2020/2nd. Grade Number of classes per week**	**2021/ 3rd. Grade Number of classes per week**	**Total of hours during the course**
Languages	Portuguese and Literature	5	5	5	600
	Arts	2			80
	Physical Education	2	2	2	240
	Total				920
Mathematics	Mathematics	4	4	4	480
	Total				**480**
Natural Sciences	Physics	2	3	3	320
	Chemistry	2	2	2	240

	Biology	2	3	3	320
	Total				**880**
Human Sciences	History	2	2	2	240
	Geography	2	2	2	240
	Philosophy	1	1	1	120
	Sociology	1	1	1	120
	Total				720
English	English	2	2	2	240
	Total				240

Participants and Data Collection

We invited all five municipal schools that offer high school level education in Taubaté to participate in our study. As newly opened schools, they only offered the first two grade levels (out of three) during our data collection in 2021. All students enrolled in high school were invited to participate in our research that consisted of answering a survey after receiving an authorization from the Secretary of Education and the directors of each school. Invitation letters were sent to parents or guardians, and a corresponding informed consent form was sent to high school students.

Due to the COVID-19 pandemic that changed how students attend schools, we provided both printed and electronic (Google Form) versions of the survey to allow for remote data collection. In schools in the central region of the city, the electronic format of the survey was implemented. We were able to gather parents' and students' interests and consent to participate in our research study through the help of administrators in our partner schools. Students received the online survey through their email addresses. On the other hand, in peripheral and rural schools, students received a printed hard copy of the survey, which they answered during their regular school activities.

Quantitative

The invitation to participate in the research was sent to all students in the five schools (a total of 915 students), and an accessibility sample was formed by 291 teenagers. The majority of the respondents identified as female (66.0%). Student ages ranged from 14 to 19 years old with the majority being between 15 and 16. Seventy-six percent of the respondents were studying during the evening class sessions and the majority (84.5%) of students answered our survey online. Table 2 presents the demographic profile of the respondents.

Table 2. Respondents´ Demographic Profile

		Frequency	Percentage
Gender	Female	192	66.0%
	Male	99	34.0%
	Other	0	0%
Age	14 years old	6	2.1%
	15 years old	118	40.5%
	16 years old	124	42.6%
	17 years old	37	12.7%
	18 years old	5	1.7%%
	19 years old	1	0.34%
Class Sessions	Day	70	24.1%
	Evening	221	75.9%
Survey Format	Online	246	84.5%
	Hard or printed copy	45	15.5%

Qualitative

The qualitative data of the study were collected from semi-structured interviews with 12 high school students from the total sample. Six male and six female students, aged between 15 and 17 years old, accepted our invitation to share with us their opinions and experiences toward sciences and mathematics in school. Based on the results from our quantitative analysis, we developed 16 questions as part of a semi-structured interview protocol (seven questions about science, seven questions about mathematics, and two questions about both disciplines) to learn more about students' awareness, perceived ability, value, and commitment. After developing the interview questions, we invited participants who had previously participated in a different study conducted by one of the researchers (Santos, 2021), in this way representing a sample of convenience. Each interview was recorded and transcribed before being analyzed and coded by the researchers.

Instruments

Quantitative Instruments

For data collection, we adapted and used the 34-item survey developed in the pilot study by Mahoney (2010) for the purposes of this research. The instrument measures high school students' awareness, perceived ability, value, and commitment toward science and mathematics disciplines inside and outside of school contexts. This study focused on science and mathematics because the high schools in our study did not focus on technology and engineering as part of their curriculum. The survey consists of 34 items divided into 4 categories (Mahoney, 2010, p.27) and students respond using Likert scales (strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree), which we describe below. This instrument was validated by Mahoney (2010) for his population of ninth and eleventh grade high school students in a metropolitan school district. According to their calculations using Cronbach's alpha, "each identified component indicated very high reliability with alpha ratings above .70" (p. 28). In our study, certain negative items were written in affirmative statements in order to facilitate understanding in the Portuguese language. Thus, each student answered 34 items for each content area (34 in science and 34 in mathematics), which resulted in a total number of 68 items. We provided the categories and items in Appendix A.

We used Cronbach's alpha, α (or coefficient alpha) to know the internal consistency of a set of questions on the Likert scale (Oluwatayo, 2012). The coefficient alpha ranges from 0 to 1, with that set of questions with a value above 0.67 being considered acceptable (Cohen et al., 2008). The set of questions regarding dimensions were: dimension 1: science=7.9, math= 8.7; dimension 2: science=6.8, math=7.7; dimension 3: science=8.6, math=8.7; dimension 4: science=8.9, math=8.9. All of them are considered consistent. After the group met to discuss the results of the survey, we realized that two of the items (3 & 28) did not provide a valid measure of awareness or commitment for our study population because these two items referenced students' awareness of and commitment to after-school programs in science or mathematics. However, as most (75.9%, n=221) of our participants attended school in the evening, these types of programs were not offered.

Qualitative

Our semi-structured interview protocol included seven questions about science, seven questions about mathematics, and two questions about both disciplines. The interviews were conducted remotely and were recorded with a voice recorder using questions or items in Appendix B. To increase trustworthiness of our interview questions and process, we conducted the following: (a) analyzed quantitative data for trends and then developed qualitative interview questions to uncover more details about why some of these trends appeared, (b) through multiple iterations and discussion, we developed a total of 16 questions to further probe the quantitative results, (c) we compared the students responses with the questions that were asked to ensure that we captured data relevant to our initial intention of clarifying some gaps in the quantitative data, and (d) one of the authors coded our raw data, while a second author acted as a peer reviewer. Finally, once we confirmed that we had captured the appropriate data for our research question, we analyzed and coded it for themes; these themes were then discussed amongst all the authors as a way of peer-debriefing to ensure that all authors were seeing the same themes.

Data Analysis

Quantitative

The data was presented from total values and proportions, using percentages of individuals who strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree. Therefore, the total number (n) of items answered varied according to specific items and dimension. Everyone answered two categories, one for science and one for math. Thus, we ran a comparison using Chi-square ($\square^2$) to proportions obtained between responses of science and math to each item of all dimensions. To perform the comparisons of proportions three response clases were considered, being (1) strongly agree + agree, (2) neither agree nor disagree, and (3) strongly disagree + disagree. Pearson linear correlations (r) were run between gender and some isolated items, being: number 29 (I am curious about a career involving science or mathematics), number 30 (I am interested in advanced programs involving science or mathematics), and number 33 (I intend to further develop my abilities). Following the study of Sadler et al. (2012) that showed how science identity changes based on gender throughout high school, we used an ANOVA one-way test (Boone & Boone, 2012) to compare differences between gender within these items (numbers 29, 30, and 33).

We used multivariate factor analysis to correlate analyzed Perceived Ability and Value Dimensions with three items: I intend to further develop my abilities, I am interested in advanced programs involving, and I struggle in science and mathematics courses. Not all items that made up the dimensions had normal distribution, and in these cases the Kaiser-Meyer-Olkin measure of sampling adequacy was observed (KMO> 0.79) for the factor. A Bartlett test of sphericity was also significant suggesting that the population was not an identity matrix. We ran multivariate factor analysis using varimax rotation and Principal Component (PC) methods to extract component factor 1 and 2 (Hair et al., 2006; Abdi & Williams, 2010). Thus, we used Pearson linear correlation between PC1 and PC2 with each chosen item. In both the multivariate analysis and Pearson linear correlations, we excluded the unique individuals who were 19 years of age and those who left items blank. This resulted in variations in the sample size (n). All analysis was performed in the SPSS statistics 20 (George & Mallery, 2019) and those results with values of $p < 0.05$ were considered statistically significant.

Qualitative

The audio recordings obtained from semi-structured interviews were transcribed into text and analyzed using qualitative content analysis. We employed qualitative content analysis to identify codes and themes from our data (Hsieh & Shannon, 2005). Conventional content analysis was applied through the following steps: the analysis started with reading all data repeatedly to achieve immersion and obtain a sense of the whole. Then, data was read word by word to derive codes by first highlighting the words from the text that appear to capture key thoughts or concepts. Codes then were sorted into categories based on how different codes are related and linked. The categories were used to organize codes into meaningful groups (Hsieh & Shannon, 2005). Several themes that emerged from our analyses were: (a) personal experiences (e.g. contact with nature, influence of shows on television and teachers) as reasons for interest in science or mathematics, (b) helping humanity, making life better, and making connections to the environment to explain importance of careers in science or mathematics, (c) positive and negative aspects of science and mathematics, as well as suggestions to improve how science and mathematics are taught in schools, including the difficulty of subject, the interactive nature of classes, and the presence of real-world experiences, and (d) extracurricular activities offered in schools and self-learning as how to learn mathematics outside of school. We provided examples from student interviews and explanations to support our quantitative findings below.

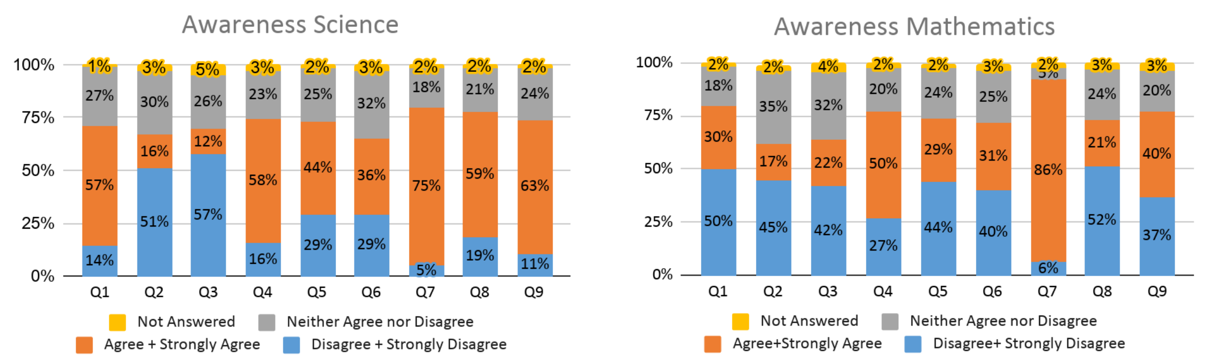
Findings

In analyzing the data from our survey, we found both similarities and differences between students' experience in mathematics and science in terms of their awareness, perceived ability, value, and commitment to these two disciplines. We present our findings in the following sections below.

Finding 1: Students' Awareness in Science and Mathematics

The first category of results addresses students' awareness of the subjects under study. Awareness means interest, recognition, knowing, consciousness, attention, curiosity, and concern of students in science and mathematics. In general, the results presented in Figure 1 reveal that students are more aware of science than mathematics.

As can be seen in Figure 1, in general, students are more aware of science than mathematics. Specifically, a significant number of students agree that they prefer science to mathematics in term of (Q1) reading materials (Diff= 27%; χ^2= 68.8; $p<0.0001$), (Q8) watching TV shows (Diff= 37%; χ^2= 92.2; $p<0.0001$), and (Q9) as a subject (Diff.= 23%; χ^2= 75.6; $p<0.0001$). Neutral respondents on (Q1) included neutral science (27%), and neutral mathematics (18%). However, it should be noted that there may not be as many television shows or reading materials about mathematics compared to science. In the interviews, interest is much more present in the science discipline than in mathematics. For instance, Gabriel made connections to science in terms of saving the environment, "*I have interest because Science can help to conserve animals. Nowadays, which is another thing that is at risk, many animals are endangered, so I think it is more to help conserve our planet that is so important to us.*" We also coded reasons why students like or dislike science and mathematics. Such reasons are related either to the characteristics of a STEM discipline or to personal experiences. As one example of this, Clara mentioned during her interview, "*I think I have no interest in mathematics because there are a lot of things and I think a little bit slowly, I need* *paper, I can't do it in my head. I think math is more difficult than science. I always found math more difficult and in high school it got more difficult.*" In this example, personal experiences are closely linked to positive or negative school experiences.



Items included:

1. I like to read about science or mathematics
2. My school offers courses in science or mathematics
3. My school offers after school programs in science or mathematics
4. I want to learn more about science or mathematics
5. I enjoy taking courses in science or mathematics
6. Courses in science or mathematics are available to me
7. Science or mathematics is challenging
8. I enjoy watching TV shows involving science or mathematics
9. I like science or mathematics

Figure 1. Awareness of Students in Science and Mathematics

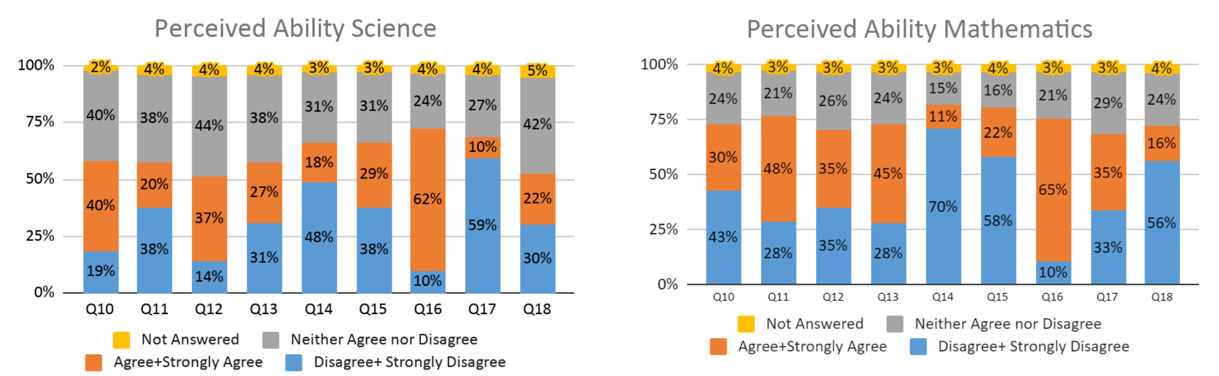
Less than one in five students agreed that they were (Q2) aware of science (16%) or mathematics (17%) course offerings at their school. In talking about their awareness of after school program offerings (Q3), 26% of the students responded neutrally to being aware of science after school offerings, and 32% of the students responded neutrally to being aware of after school mathematics offerings (Q3). Nearly (12%) of the students responded they are aware of the after school science programs and (22%) responded they were aware of the mathematics offerings, with neutrally science (26%) and mathematics (32%) responses. Reinforcement classes occur twice a week. The students can make an appointment with the teacher to answer their questions through the WhatsApp application or, if they prefer, they can schedule a time and go in person at school. Moreover, nearly twice as many students who agreed on (Q2) also agreed that (Q6) science (36%) and mathematics (31%) courses were available to them (neutral responses science (32%) and mathematics (25%)). This seems to suggest that students may not have fully understood the item and that there may not be an overall consensus of student responses.

In the interviews, some students suggested connecting mathematics to students' everyday life experience. As Isabela said, "*I think that giving more examples of everyday life would help a lot. I think that if they had more participatory classes it would help too much, where students would have more freedom to learn in various ways, answer questions and everything. More dynamic classes would be much better.*" This example also suggests for teachers to incorporate active learning into their instruction. At least a quarter of the students responded with neither agree nor disagree options for (Q2) or (Q3). For the purposes of our analysis we regard the neither agree nor disagree response as neutral. Note that since the majority of students (76%) are taking courses in the evening there are no after school programs available to them. Moreover, we are uncertain about their notion of what "courses" mean compared to disciplines (see Table 3). At least half of students (Q4) want to learn more about science (58%) or mathematics (50%; $\chi^2 = 64.74$; $p=0.033$).

The majority of students (about 75%) agree that (Q7) science and mathematics are challenging for them. However, mathematics is more challenging than science ($\chi^2 = 132.3$; $p<0.0001$). This was confirmed in our interviews with students. Some students confirmed that they do not like mathematics because it is difficult and requires a lot of effort. The difficulty increases as they progress through the grades. In this response from Teresa, she said that she is not interested in mathematics because it is challenging to understand, saying *"I am not interested and do not like the discipline of mathematics because the subject does not enter in my mind, and I do it because it is obliged, if I could exclude it, I would exclude it.*" Moreover, some students such as Miguel mentioned that teachers and their ability to teach mathematics can encourage students to learn this subject, "*I think the way that mathematics is taught at school is good, but it varies a lot according to the teachers, you know, there are some teachers who are clearer and others who don't even have the willpower. They say they've already taught and they don't even take the doubts…. really wrong.*" Although many students expressed that (Q9) they liked science (63%), not as many like mathematics (40%). Moreover, not as many students (Q5) indicated that they enjoyed taking science (44%) and mathematics (29%) courses. Our results suggest that students prefer science over mathematics, as (Q9) 23% more students indicated that they liked science than mathematics (χ^2= 24.76; p<0.0001). Additionally, (χ^2= 9.047; p= 0.002) 15% more students agreed that they enjoyed (Q5) taking science courses than taking mathematics courses. Nearly a quarter of the respondents responded neutral to (Q5) and over one in five responded as neutral on (Q9).

Finding 2: Students' Perceived Ability in Science and Mathematics

Finding 2 presents students' perceived ability in Science and Mathematics. It means the way students perceive their capacity, skills, confidence and self-belief in relation to Science and Mathematics. In general, students have a low perceived ability in science and a slightly lower perceived ability in mathematics. All the results can be seen in Figure 2.



Items included:

10. I am good at projects involving science or mathematics
11. Science or mathematics is difficult for me
12. I perform well in science or mathematics courses
13. I cannot handle advanced courses in science or mathematics
14. Science or mathematics is simple
15. I do not worry about taking tests in science or mathematics
16. I struggle in [subject] courses science or mathematics
17. I do not understand science or mathematics
18. Homework in science or mathematics is easy

Figure 2. Perceived Ability in Science and Mathematics

As shown in Figure 2, over six out of ten students agreed that they struggled with science (nearly 62%) and mathematics (nearly 65%) courses (Q16; χ^2= 0.132; p= 0.71). Additionally, three times more students agreed that they do not understand mathematics (nearly 35%) as compared (Q17) to science (nearly 10%; χ^2= 40.18; p=0.0001). As an example, Sophia notes the difference in effort required between science and mathematics as a factor in understanding, "*My class likes science more because many are a little lazy. So science doesn't have much to do. Mathematics is already more complex, it has more accounts, more tasks ... that's why.*" This example also demonstrates how Sophia perceives mathematics as more complex than science. Moreover, more students perceive themselves to be good (Q10) with science projects (about 40%) as compared to mathematics projects (about 30%; χ^2= 3.44; p<0.063). While it is true that just as many students responded neutrally to this item, we believe that this is still a valid finding because many more students disagreed or strongly disagreed with this prompt in mathematics (43%) than in science (19%).

Nearly half (about 48%) of the students agree that (Q11) mathematics is difficult for them, as compared to nearly a fifth (about 20%) who perceive science to be difficult (χ^2= 34.79; p<0.0001). Approximately four in ten (38%) students responded neutrally to difficulty with science and one in five students (21%) responded neutrally to perceiving mathematics as difficult. For example, in talking about personal experiences in dealing with the subject or learning difficulty with mathematics, Miguel states, *"I was never a grade ten student in mathematics, but I always tried. I think math is too difficult. My effort was never enough, but after you go to high school it becomes almost impossible if you don't have a good base*." Speaking of his low perceived mathematics ability Gabriel, who finds it to be a difficult subject compounded by his lack of interest states, "*I'm not very good at math, you know… I was never 100 percent interested. I don't think I'm interested in math because I can't spend a lot of time thinking. I'm the type who has to do something, I have to go after it, you know, math I kind of get bored."* On the other hand, Teresa, noting her low perceived ability in mathematics, feels deterred, stating, "*I don't think anything discouraged me, I never liked it and I was never good at math.*" From these comments, it seems low perceived ability, low subject interest and difficulty learning are leading to low mathematics achievement.

Nearly an even split of the students (Q12) perceived they performed well in science (about 37%) or mathematics (about 35%) courses (χ^2= 0.07; p=0.78). This is interesting given that nearly half found mathematics to be more difficult. Approximately a quarter of the students responded neutral to performing well in mathematics as compared to the nearly four in ten (44%) in science. In the case of Valentina, mathematics is more interesting than science, "*I do better with math than science, even though I don't like either one very much*." Valentina is also motivated to learn mathematics as she is engaged with the subject, "*Math is more logical. I like to keep thinking about every exercise I can complete. I get super excited and motivated*." Easy subject comprehension is credited by Rafael who describes how easily he understands mathematics, "*With regard to mathematics, I think I always liked it more, because I always had a lot easier. There were times when I didn't even need to study for exams, I left to study at the last minute and I was doing really well, it was always a discipline that I took super fast, it was a discipline that I have ease, so it was always more fluid for me, I always liked it and I was interested in having it easier, so I liked it and I like it."* These qualitative comments regarding motivation to learn and easy comprehension because of interest lead us to believe that student subject motivation could potentially contribute to perceived higher subject achievement.

While the majority of students mentioned mathematics is more challenging than science, in our interviews we also saw students who mentioned that science is a challenge. In speaking about his personal experience with difficulty with advanced science courses, Iago remarks "*Regarding the science discipline, I'm bad, you know, speaking the truth, I think it wasn't even discouraged, it was because I can't understand the subject anymore, it was more in high school, because in elementary school I was going well, I understood well, but in high school it was complicated. Entering the periodic table and such, and then everything went bad, I got lost in everything*." . Thinking of the science subject content Miguel states "*In terms of the science discipline, I'm not a fan, but I try to understand it, but I'm not very good. It is difficult for me*." While Gabriel notes his lack of interest in mathematics as the reason for not paying attention in class. According to Gabriel, "*I think my boredom in math class is not due to the way the subject is taught, but when I'm there in the middle of the account I end up missing something and I have to go back again, then I get discouraged because I wanted to do it, then I have to return these things all over again. math is important, I pay attention, I work on math."* These qualitative comments describe the student's low perceived ability due to increased subject difficulties, and low subject interest.

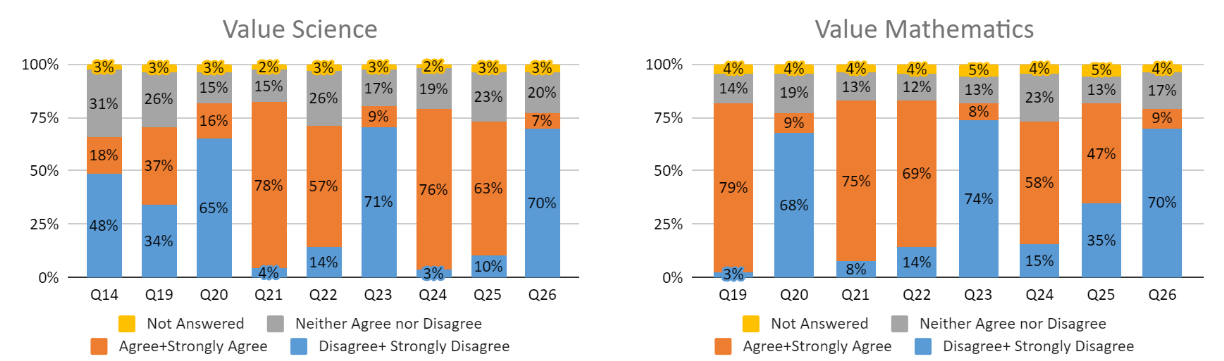
Less than a quarter of the students agreed or strongly agreed that homework in mathematics (nearly 16%) and science (nearly 22%) is easy (Q18; χ^2= 2.265; p= 0.13). On the other hand, nearly twice as many students disagreed or strongly disagreed that mathematics homework is easy (56%) as compared to science homework (30%). This suggests to us that students have a greater perceived ability in science than in mathematics. Close to six in ten students (58%) responded they worried about (Q15) taking tests in mathematics and close to four in ten responded they worried about taking tests in science (38%). Neutral science responses (31%) were almost double than those for mathematics (16%). (χ^2= 0.007; p= 0.93). Similar to the results from (Q11), this further supports our assertion that more students find mathematics difficult as compared to science. Like with our other data points, this indicates to us that, while students have a relatively low perceived ability in both mathematics and science, students have a greater perceived ability in science than in mathematics.

Finding 3: Students' Value of Science and Mathematics

The third category of results addresses students' value of science and mathematics, meaning the significance, importance, merit and usefulness assigned to the subjects. Our findings, which can be seen in Figure 3, indicate that a majority of the students expressed that they valued science and mathematics.

As shown in Figure 3, approximately eight in ten students agreed (nearly 79%) that mathematics was important but only half this number of students (nearly 37%) agreed that science was important (Q19; χ^2= 14.71; p=0.0001). Neutral student responses (Q19) included 26% science and 14% mathematics. Addressing the importance of mathematics in careers, Lucas states "*These careers are too important, mainly due to the economy, numbers, values, quality of life, jobs, etc. Mathematics is definitely in everything. I didn't like it and didn't want to, but now I'm interested in economics.*" This is again interesting because even though nearly half found mathematics to be more difficult (Q11), they still see the value in taking mathematics. This suggests to us that, while many students value both science and mathematics, more students value mathematics when compared to science. For students like Lucas, this may be due to an alignment between mathematics and potential career choices.

The appreciation of both areas is also evident in the interviews. In the sciences, there is an appreciation of the area linked to the idealization that sciences can save the world and humanity. In mathematics, valuation is linked to its usefulness in everyday life. For example, Gabriel, noting the importance of careers involving science, remarked, "*Science careers are* *important to change the world*." Gabriel also articulates the importance of a career in mathematics, stating that while he does not personally feel it is for him, "*I've never been interested in any math career, but it's important.*"



Items included:

19. Science or mathematics is important
20. What I learn in science or mathematics has no value to me
21. I believe there is a need for science or mathematics
22. I need science or mathematics
23. Learning science or mathematics will not help me
24. Science or mathematics is good
25. I care about developments in science or mathematics
26. Science or mathematics is not worth my time to understand

Figure 3. Value in Science and Mathematics

A majority of the students (at least 65%) disagreed that they saw no value in what they learn (Q20) in science (65%) and mathematics (68%). Nearly 15% of the students responded neutral to science and nearly 19% of the students responded neutral to mathematics (Q20). This suggests to us that students value both mathematics and science. For example, Clara values science because of its connection to humanity. In her own words, this is *"because I like to see people helping other people. Science can help people. Science can help humanity*." Further, when talking about the importance of science careers, Isabella remarks, "*These careers are important because they bring evolution to society."* These students' assertions show that they value science and mathematics because of its importance in promoting and sustaining human society.

Further, over three quarters of the students agreed that there is a need (Q21) for science (78%) and mathematics (75%); while another 15% science and 13% mathematics responded neutral (χ^2= 0.02; p=0.88). The results for Q22 are interesting as even though nearly three quarters of the students agreed there is a need for science and math (Q21), far less of them agreed they themselves need science (57%) and mathematics (69%; χ^2= 1.03; p=0.31). Neutral student responses (Q22) included 26% science and 12% mathematics. This also makes the findings in Q23 more interesting as nearly over 70% of the students disagreed that learning science (9%) or math (8%) will not help them (Q23; χ^2= 0.00; p=0.99). Neutral (Q23) responses include 17% science responders and 13% mathematics responders. As well as Q26 where nearly 70% of the students agreed that it was worthwhile to take the time to understand science (70%) and mathematics (70%; χ^2= 0.00; p=0.99). Neutral student responses (Q26) include 20% science and 17% mathematics respectively. Taken together, this may indicate that, while many students see value in science and mathematics on a societal level, fewer students may value science and mathematics on a personal level.

From our interviews, we see that certain students do value science and mathematics on a more personal level when it relates to a future career they are interested in pursuing. For example, Valentina remarks, "*What I want for my life is IT. Computer science has a lot to do with mathematics. Math makes life easier, makes us think better, and faster and I think it has more benefits than science.*" Here, Valentina indicates that she values mathematics more than science, in part because her future career (IT/Computer Science) depends more on mathematics than science. Julia, on the other hand, notes, "*They serve to help humanity, so they are important, to help us. I am interested in the science career and it is in medicine.*" Similar to Valentina, she places more value on the discipline she sees as more relevant to her future career, in this case valuing science for her future career choice of medicine.

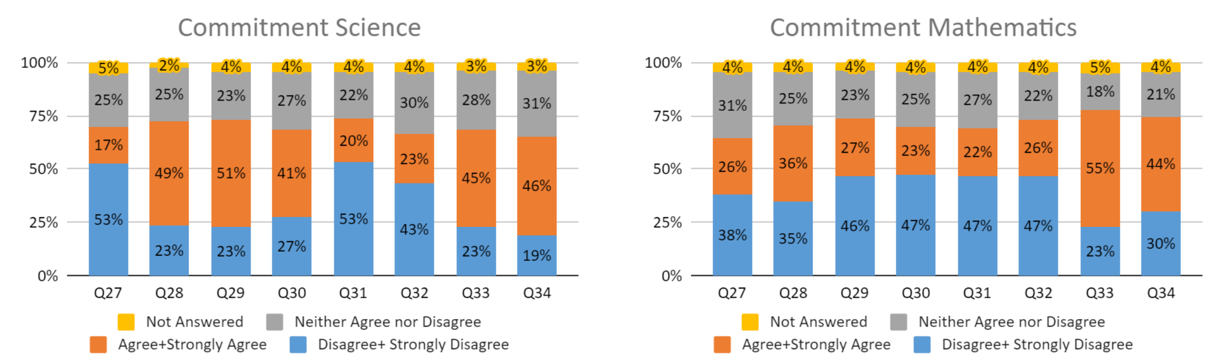
Figure 3 shows that nearly 18% more students agreed (Q24) that science (76%) was good as compared to mathematics (58%; χ^2= 3.026; p=0.081). Neutral student responses (Q24) include 19% science and 23% mathematics respectively. Similarly, nearly 20% more of the students agreed they cared about the developments (Q25) in science (63%) as compared to mathematics (47%; χ^2= 3.167; p=0.0). Neutral student responses (Q25) included 23% science and 13% mathematics.

Finding 4: Students' Commitment in Science and Mathematics

Findings 4 address students' commitment in Science and Mathematics. It means dedication, devotion, perspective and intention regarding the areas. When asked (Q27) if students would dislike more/advanced courses in science or mathematics, less than one fifth of students (17%) in science and just over one fourth of students (26%) in mathematics indicated that they agreed or strongly agreed (see Table 6). While a majority (53%) of students indicated that, for science, they disagreed or strongly disagreed, in math only 38% responded this way, as 31% of students indicated a neutral response for this item. These results suggest that while students express commitment in both science and mathematics, more students show commitment in science than in mathematics. (52.6% vs 38.1%, thus χ^2= 2.01; p= 0.15). For example, Gabriel, making connections to the vast and diverse science content states, "*I have interest in Science because it is an area that we always have something new to learn.*" Julia notes her interest in mathematics in terms of effort: "*I like math better because it was always easier for me since I was a kid*." This shows commitment or long term interest is affected by course content and required effort.

Figure 4 shows all the findings regarding commitment in Science and Math. As it can be seen in Figure 4, nearly half (49%) of the students agreed they would like to (Q28) participate in after school science programs (χ^2= 1.69; p= 0.19). Clara would like to participate in additional activities such as, "*Teach through travel. For example, taking students on a field trip."* Additionally, Clara notes "*When students have difficulty in the subjects, the school offers tutoring, but I never participated."* Miguel notes that he too would like to participate in additional activities, *"It is possible to learn science outside of school through excursions, but I never went, I wanted to, but I didn't go*." Gabriel notes tutoring may be a helpful extra class activity offered by school, "*I think it is possible to learn math outside of school through extra courses. I know people who take extra math courses, tutoring because of falling grades*." And Lucas noting the internet enables learning states, *"I think it's super easy to learn outside of school. Especially in pre-university courses, on digital platforms such as youtube*." These qualitative responses show that the students are open to a variety of extra-curricular activities.

While this appears to be a clear indication of students' commitment to science, the responses in mathematics were divided almost evenly between agree/strongly agree, neutral, and disagree/strongly disagree. In both cases, this is interesting as the majority of the students attend night school and as such there are no after-school activities offered by the school. Activities before school starts in the evening are limited in space and resources because time and space are being used by elementary grade classes. This shows commitment on the part of the students to engage in such activities in science, but not as much so for activities in mathematics.



Items included:

27. I would dislike more/advanced courses in science or mathematics
28. I would like to participate in more after-school programs in science or mathematics
29. I am curious about a career involving science or mathematics
30. I am interested in advanced programs involving science or mathematics
31. I have no interest in discovering new ways to apply science or mathematics
32. Science or mathematics is not a vital part of my perceived future
33. I intend to further develop my abilities in science or mathematics
34. I will continue to enjoy the challenge of science or mathematics

Figure 4. Commitment in Science and Mathematics

Nearly 24% more students expressed (Q29) curiosity in a science (51%) related career as compared to mathematics (27%), and neutral student responses included 23% each for science and mathematics (χ^2= 6.71; p= 0.009). Speaking about science careers Clara speaks, "*Sciences will help our environment. And this is something I worry about, because if we don't take care now, in the future we will have nothing.*" Also, Miguel remarks on the importance of mathematics careers, "*I think these careers are important because it is in everything, it helps in everything."* These comments demonstrate that students understand the importance of science and mathematics careers.

Approximately a quarter of the students expressed interest in (Q30) advanced mathematics careers (23%) and slightly more than four in ten students expressed interest in advanced programs in science (41%), (χ^2= 4.45; p= 0.034). Neutral student responses (Q30) include 27% science and 25% mathematics. Taken together, this suggests to us that students express more commitment in science than in mathematics. For example, Lucas links his science interest to TV shows, "*I have much interest in Science ... what really influenced me was the series Gray's Anatomy."* While Hugo notes teacher influence as the reason for his science interest, "*I think that this year that I started to like science more, in the last year I didn't like it very much, now that it is divided into several parts, I started to like it more. I think it was for my teacher, I like the way he teaches*." In the interviews, the greater interest in careers in the sciences area is also evident. Perhaps the lack of interest in careers in mathematics is linked to the fact that they find mathematics difficult and have little knowledge about careers related to mathematics.

Close to a quarter of the students agreed that they (Q32) did not see science (23%) and mathematics (26%) as a vital part of their perceived future (χ^2= 0.66; p= 0.79). Neutral student responses (Q32) include 30% science and 22% mathematics. This further suggests to us that students have a commitment to both science and mathematics. From our qualitative data, we see continued connections to careers as motivators for students' commitment in science and/or mathematics. For example, Gabriel is interested in environmental conservation and animals speaks about the importance of science careers: "*It helps to conserve animals, nowadays animals are at risk, many animals in extinction.*" Similarly, Rafael links his daily work to math interest, "*I like math and Portuguese more, because I currently work for a company in the financial sector. So daily I work with numbers, with calculations, so math for me has always been important, I have always been hard working and it has always been my strong point*." In both cases, students are connecting their future (or sometimes present) jobs and careers to their commitment in science and mathematics.

Only a small number of the students (roughly 20%) expressed a disinterest in discovering new ways (Q31) to apply science (20%) or mathematics (22%; χ^2= 0.02; p= 0.87). Nearly half of students reported they intend to further develop their abilities (Q34) in mathematics (44%) and science (46%; χ^2= 0.81; p= 0.36). Neutral responses (Q34) included 31% science and 21% mathematics responses. This suggests to us that most students have a commitment to both mathematics and to science. That said, some other students, such as Isabella, did not express a commitment in science and/or mathematics. Isabella explains, "*Nothing makes me interested in science"* and also notes "*I am not interested in any professional career that involves mathematics, but maybe gastronomy involves a little bit, right? I think so, I'm not sure*." Again, however, we note a connection between students' commitment to mathematics and science and their perceived future career options.

Finding 5: No Gender Differences

In findings 5 comparisons of responses according to gender will be presented. Figure 5 reveals that there are no gender differences regarding the analyzed items.

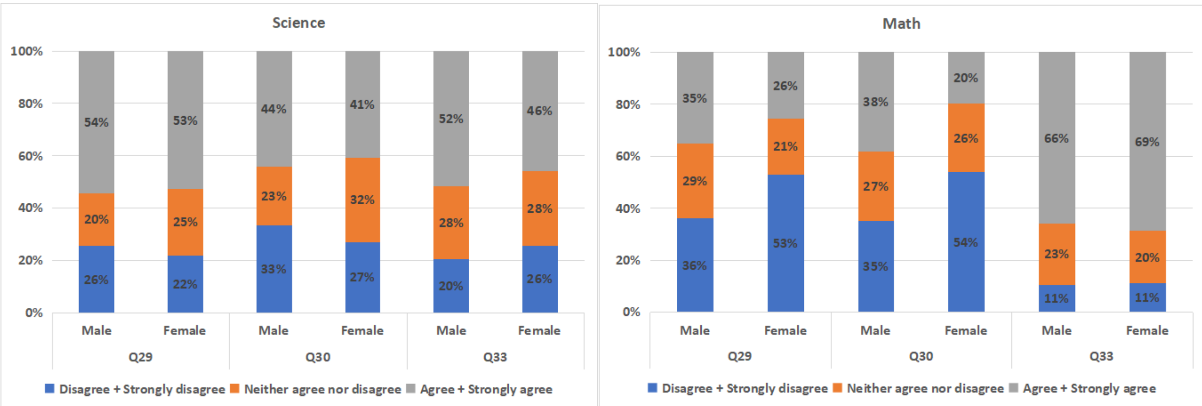


Figure 5. Gender Distribution

Item 29: I am Curious About a Career Involving Math and Science

The results of this item (Q29) did not show significant differences between males and females. For math, of the total 93 male respondents, 34 (36%) responded disagree or strongly disagree, while 33 (35%) responded agree or strongly agree and 27 (29%) responded neutral. Similarly, of the 181 female respondents, 97 (53%) responded disagree or strongly disagree, while 47 (26%) responded agree or strongly agree, with the remaining neutral responses at 39 (21%). Although females disagreed more about their interest in following careers involving mathematics, this difference was not significant. ($F = 0.11$; $p = 0.76$). For males, the number of students who disagreed and agreed was even more similar. These results were influenced by the large number of neutral responses, which seems to show a lack of future perspective of approximately 20% of both groups evaluated. This is apparent in Julia's speech: "*With regard to the discipline of mathematics, I like it. My father and uncle influenced me to like mathematics, because they are from the field, my father is a civil engineer and works with a lot of calculus*." In Julia's case, family influence allows the student to have a future goal based on her paternal career.

The results regarding willingness to pursue careers involving science had similar results. That is, even though there was greater interest from students, both males and females, these differences were not significant (F= 0.00; p= 0.94). Of the total 94 male respondents, 24 (26%) responded disagree or strongly disagree, while 51 (54%) responded agree or strongly agree and 19 (20%) responded neutral. Similarly, of the 183 female respondents, 40 (22%) responded disagree or strongly disagree, while 96 (53%) responded agree or strongly agree, with the remaining neutral responses at 46 (25%). Thus, once again, the number of neutral responses was high for both groups, 22%, evidencing the lack of future perspective, even knowing the importance of careers involving knowledge of science. Clara notes careers in science and math are important but not for her on a personal level: "*I have no interest in a career that involves mathematics, because to have a career in mathematics you have to be very interested and I don't. I think that careers that involve mathematics are important, for example the engineer, architect, physicists, mathematicians, etc.*"

Item 30: Interest in Advanced Programs Involving Math and Science

Similar to curiosity, all items that involved future perspectives (Q 30) did not show significant differences between males and females, both for science (F= 0.79; p= 0.78) and for math (F= 1.87; p= 0.11). For science from the total 93 male respondents, 31 (33%) responded disagree or strongly disagree, while 41 (44%) responded agree or strongly agree and 21 (23%) responded neutral. Similarly, of the 181 female respondents, 49 (27%) responded disagree or strongly disagree, while 74 (41%) responded agree or strongly agree, with the remaining neutral responses at 58 (32%). In this case, the number of neutral responses was even higher (~30%), evidencing the absence of future interest from both genders.

For math, when analyzing 94 male students, 36 (38%) agreed or strongly agreed while 33 (35%) disagreed or strongly disagreed, with 25 (27%) students responding neutrally with respect to interest in advanced programs involving math. Out of 182 female students, 36 (20%) agreed or strongly agreed, 98 (54%) disagreed or strongly disagreed, with 48 (26%) neutral responses. These responses indicate that there is no significant difference between male and female students' interest in pursuing advanced programs involving math, even being the number of females who disagree 20% more than males who also disagree.

Item 33: I Intend to Further Develop My Abilities in Science and Math

About the interest in developing personal abilities in the future for the field of science (Q33), there were also no significant differences between male and female (F= 0.61; p= 0.43). Of the total 93 male respondents, 19 (20%) responded disagree or strongly disagree, while 48 (52%) responded agree or strongly agree and 26 (28%) responded neutral. Similarly, of the 183 female respondents, 47 (26%) responded disagree or strongly disagree, while 84 (46%) responded agree or strongly agree, with the remaining neutral responses at 52 (28%). The results show that this equality is true, since most of both males and females agree to develop personal abilities in the field of science. Rafael notes "*Science is a very interesting subject that addresses very cool issues that I like a lot.*"

For math there was also no difference between males and females (F= 0.00; p= 0.92). Of the total 94 male respondents, 10 (11%) responded disagree or strongly disagree, while 62 (66%) responded agree or strongly agree and 22 (23%) responded neutral. Similarly, of the 182 female respondents, 20 (11%) responded disagree or strongly disagree, while 125 (69%) responded agree or strongly agree, with the remaining neutral responses at 37 (20%). Interestingly, the number of male and female respondents who agreed and strongly agreed to develop math abilities in the future was high, even though the vast majority, especially girls, do not like math. Lucas links math skills to job security, "*I am interested because I think that math is in everything, so thinking about the profession is an area that I will always be busy and employed*." But Isabella is not interested in math, as she notes, "*About mathematics, I have no interest in mathematics, I cannot understand much, some parts of mathematics I cannot learn anything. I think math is very difficult*."

Discussion and Conclusion

We conducted this study to inquire and answer this research item: *What are Brazilian high* *school students' awareness, perceived ability, value, and commitment to science and mathematics?* Our findings suggest that students are more aware of science compared to mathematics. Additionally, students prefer science over mathematics, but not as many students indicated that they enjoyed taking these courses. While most students seemed to have low perceived ability in both disciplines, more students expressed a greater perceived ability in science than in mathematics. When describing the value students placed on science and mathematics, the majority of the students indicated that they both valued science and mathematics, although many did not place the same amount of value on each discipline. Finally, we found more students showed commitment in science than in mathematics. This suggests to us that students have stronger science identities than mathematics identities. This is interesting to note, as other research studies focused on students' science and mathematics identities, motivations, and attitudes did not analyze science and mathematics identity separately, but instead reported STEM identities as a singular construct (e.g., Foud, 1995; Goff et al., 2020; Hughes et al., 2013; Paul et al., 2020). Following the work of Starr et al. (2020) that saw student engagement in authentic science practices was an important factor in strengthening students' motivation and identity in STEM subjects, our results suggest that personal experiences of high school students are closely linked to their positive or negative experiences in school. Our qualitative data seems to provide support to Starr et al. (2020) that noted teachers' active engagement of students during instructional activities is valuable to increase student awareness in mathematics and science. For instance, Isabela mentioned that real life connections, an independent approach to learning, and active engagement could help her become more aware of science.

Goff et al. (2020) analyzed math and science competence together as a singular variable and found that students who participated in informal mathematics and science environments expressed more self-competence than students who did not participate in these informal learning environments. However, compared to their study that did not separate math and science competencies, we saw that, while most students seemed to have low perceived ability in both disciplines, more students expressed a greater perceived ability in science than in mathematics. When describing the value students placed on science and mathematics in our study, we found that the majority of the students indicated that they both valued science and mathematics, although many may not place the same amount of value on each discipline. Unlike Rice et al. (2013), who connected students' attitudes and values in mathematics and science with the amount of support they received from parents, teachers, and friends, the students we interviewed connected their value of science and mathematics with each discipline's perceived usefulness in everyday life and students' potential future career choices. The value students place on these disciplines is important, as findings from Topçu et al. (2016) indicate that students in Turkey and Korea who valued science and mathematics were significantly more likely to perform well in those disciplines. As in our study, they analyzed students' value of both mathematics and science separately and found that they had similar levels of perceived value in both disciplines.

In examining students' commitment, or long-term interest, in science and mathematics, we saw that more students show commitment in science than in mathematics. This finding is important, as student interest in STEM disciplines is strongly correlated with their determination to pursue and persist in schooling and careers in STEM after high school (Paul et al., 2020). We propose that this observed lack of interest in careers in mathematics is linked to the fact that students find mathematics difficult and evidence little knowledge about careers related to mathematics. Campos (2021) identified that perception of performance in mathematics is a variable that strongly implies in the intentions of students to follow or not careers in the area of mathematics, showing that mathematical anxiety is more directly related to the negative perceptions of mathematical skills of students, causing disinterest in the career in this area. Similarly, other researchers have shown that students who exhibit a strong STEM identity may be more motivated to pursue STEM majors and careers upon completion of high school (Dou et al., 2019; Wentzel, 1998). For example, Dou et al. (2019) found a strong, positive relationship between college freshmen with strong STEM identities and their tendency to pursue STEM careers. Similar to how Dou et al. found that certain childhood experiences, including conversations with peers and loved ones about STEM and engaging with non-fiction STEM resources, had a profound impact on the development of students' STEM identities, we also found some evidence of this in our interviews with students. In the same direction, Buschor, Berweger, Keck Frei and Kappler (2014) studied whether young Swiss high school graduates, who intended to study science, technology, engineering and mathematics - actually enrolled in these careers in higher education two years later, and how these young women perceived this process. According to the authors, the young women demonstrated persistence in pursuing careers in the STEM field. In a qualitative analysis, the authors state that the decisive factors for the students' choices in the STEM field were learning experiences, parental support and reference models. Also interesting are the findings of Sadler, Sonnert, Hazari and Tai (2014). They studied the relationship between the choice of advanced science and mathematics courses in secondary education and the interest in pursuing careers in the STEM field in higher education. The authors concluded that the number of years young people spend studying advanced science and advanced math in secondary education is associated with increased interest in STEM careers - especially in math, chemistry and physics.

Similar to the work of Mahoney (2010), who did not find any significant differences due to gender in students' attitudes toward STEM, in our study, we found that both male and female students are curious and willing to pursue careers in math and science at statistically similar rates. However, unlike the study of Goff et al. (2020) who saw male students perceive higher levels of competence in math compared to female students, our findings suggest that there were no significant differences between males and females with regards to their interest in advanced programs and intention to further develop their abilities in math and science. Historically, STEM professions are mostly occupied by men. The growing entry of women in these areas in recent years, in Brazil and worldwide, has raised the debate about diversity in the areas of Science and Technology. The choice for an academic career in the field of STEM is influenced by various social, economic and cultural aspects (South American Institute for Fundamental Research, 2019). Thus, more research exploring gender differences and the influences of all these aspects becomes very important.

Implications of Study

Bearing in mind the importance of stimulating and encouraging the inclusion of young people in the areas of science, technology, engineering and mathematics (STEM), this research aimed to understand Brazilian high school students' awareness, perceived ability, value, and commitment to science and mathematics. Taking as an empirical source 291 teenagers, who answered a survey, and 12 high school students who participated in semi-structured interviews, some conclusions were reached that illustrated the implications of this study. Specifically, we saw that students connected their value of science and mathematics with each discipline's perceived usefulness in everyday life and their potential future career choices. Therefore, in order to better motivate students in science and mathematics, teachers should attempt to relate their lessons and discipline to students' everyday lives and career interests. Additionally, we found that the lack of interest in careers in mathematics may be linked to the fact that students find mathematics difficult and they have little knowledge about careers related to mathematics. This further implicates the need for more connections between STEM disciplines and students' career interests in the classroom. Our study also indicated that students expressed a desire to have more dynamic and engaging classes, with themes and activities related to everyday life, and that students showed interest in having access to extracurricular activities, which would bring greater motivation to the learning process. Taken together, these findings show how curricular and pedagogical shifts towards making content relevant to students in science and mathematics classrooms could have positive effects on student's STEM identity, motivation, and engagement in STEM disciplines.

The conclusions reached show how our study can potentially help teachers to develop classroom environments that will support students to develop their STEM identities. In particular, as found by Archer et al. (2012) and Stolk et al. (2018), teacher pedagogical practices can either strengthen or weaken students' motivation to learn STEM disciplines. According to Sadler et al. (2012), the teaching methodology used in a STEM classroom greatly affects the science course experience. Science course teaching and STEM related activities should seek to engage all genders equally. Prior successful exposure to STEM courses, coupled with positive perceived ability can increase commitment to pursue STEM careers (Wang, 2013). Making classroom activities useful and relevant to the student's lives ensures STEM course engagement (Deci, Vallerand, Pelletier & Ryan, 1991). In this direction, an article developed by a Brazilian researcher (Pontes, 2018) brings reflections about the art of teaching and learning Mathematics in Basic Education in Brazil**.** The author argues that "researchers in the areas of Mathematics Education, with emphasis on the process of teaching and learning mathematics, show that the individual learner, when involved in situations that arouse his curiosity, learns in action, as he feels attracted and motivated to new discoveries, and in this way, the teacher is essential as the subject responsible for promoting these situations in the classroom". (p.164). Thus, the mathematics teacher, as mediator of knowledge, must find new didactic strategies that can involve the student in the construction of mathematical knowledge. The teacher must take into account all the student's personal dynamics, that is, the teacher must have knowledge of his student.

The student's act of learning is strengthened when there is the necessary motivation to bring the presented models closer to students' reality. The learning process is effective when students realize that the relationships of the mathematical models presented in the classroom are associated with their daily lives (Pontes, 2018). Development of students' STEM identity and motivation is important for developing their intention to pursue careers in STEM (Wentzel, 1998). For example, Paul and colleagues (2020) found a strong correlation between interest during schooling and future career paths in the STEM disciplines. It follows, then, that educators should strive to implement learning activities in their classrooms that are engaging and meaningful for students, so as to strengthen students' STEM identities. Additionally, Wentzel (1997) also notes that teacher support has the biggest effect on developing and sustaining student interest in STEM. Our research evidenced not only the importance of the teacher's role in the adoption of innovative and engaging pedagogical practices in order to motivate the student and contribute to the development of the STEM identity, but also showed that the studied teenagers want more engaging and thought-provoking classes. Thus, the importance of working on teacher training for the STEM area is shown to be a very relevant and necessary aspect in the studied reality.

Another highlighted aspect is the fact that the studied students know little about careers involving mathematics. This highlights the importance of developing actions/activities to bring up-to-date information to students about careers. As suggested, we have the possibility of holding trade fairs, lectures with professionals in the area, guided visits to institutions and organizations to get to know the daily professional work. These are low-cost activities that could provide a more consistent knowledge of the reality of the local labor market and have a positive impact on the students' professional choice process.

About research methods, it is important to acknowledge that there are multiple ways of measuring STEM identity through both quantitative and qualitative means, and as such, our study represents just one, primarily quantitative, mode of STEM identity exploration. Therefore, researchers should consider multiple avenues of inquiry when designing future studies. For example, Godwin et al. (2020) note the need for research that examines "specific connections to the classroom or interventions that may promote the development of a positive STEM identity with students" (p. 273). Additionally, Hannula et al. (2016) articulate the need for a larger focus on interviews as opposed to classroom interactions, as well as for identifying and using quantitative instruments to measure short-term changes in identity in mathematics education.

Limitations of Study

As with any research study, this study comes with several limitations. For example, although we conducted a statistical analysis for a large student population, we were not able to include a comparison group. Comparison groups are important as they help to understand what would be the result had the intervention not been implemented (Urban Institute, n.d.). Additionally, as an exploratory study, we were not able to include STEM programming for students at this time. Such STEM experiences could potentially provide information regarding changes in students' STEM identities as a result of intervention. Another limitation was related to the number of respondents between genders. Since the sample was selected by convenience, the number of males and females was not equal, with the number of males being half the number of females. This sample imbalance made some comparisons between genders inconsistent. It is suggested that new studies should be implemented with the formation of a proportional stratified probabilistic sample, which would bring greater accuracy in the analysis of differences. Finally, while we did link our findings to the STEM identity frameworks put forth by Hazari and colleagues (2010) and Eccles (2009), we did not include a measure for recognition, which is a major element of Hazari and colleagues' (2010) identity framework.

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Appendix A

The first category, awareness, pertains to interest, recognition, knowing, consciousness, attention, curiosity, and concern of students in science and mathematics. Items included:

1. I like to read about science or mathematics
2. My school offers courses in science or mathematics
3. My school offers after school programs in science or mathematics
4. I want to learn more about science or mathematics
5. I enjoy taking courses in science or mathematics
6. Courses in science or mathematics are available to me
7. Science or mathematics is challenging
8. I enjoy watching TV shows involving science or mathematics
9. I like science or mathematics

In the second category, perceived ability, students weigh in on their capability, skill, be able to, confidence, certainty, and self-belief in science and mathematics. Items included:

10. I am good at projects involving science or mathematics
11. Science or mathematics is difficult for me
12. I perform well in science or mathematics courses
13. I cannot handle advanced courses in science or mathematics
14. Science or mathematics is simple
15. I do not worry about taking tests in science or mathematics
16. I struggle in [subject] courses science or mathematics
17. I do not understand science or mathematics
18. Homework in science or mathematics is easy

With regards to the third category, value, students answered items regarding worth, significance, importance, usefulness, merit, and regard to science and mathematics. Items included:

19. Science or mathematics is important
20. What I learn in science or mathematics has no value to me
21. I believe there is a need for science or mathematics
22. I need science or mathematics
23. Learning science or mathematics will not help me

24. Science or mathematics is good
25. I care about developments in science or mathematics
26. Science or mathematics is not worth my time to understand:

In the final and fourth category, commitment, students weigh in on their pledge, dedication, devotion, potential, prospective, and intention to learn science and mathematics. Items included:

27. I would dislike more/advanced courses in science or mathematics
28. I would like to participate in more after-school programs in science or mathematics
29. I am curious about a career involving science or mathematics
30. I am interested in advanced programs involving science or mathematics
31. I have no interest in discovering new ways to apply science or mathematics
32. Science or mathematics is not a vital part of my perceived future
33. I intend to further develop my abilities in science or mathematics
34. I will continue to enjoy the challenge of science or mathematics

Appendix B

Section A: Questions about science

1. Are you interested in science? If yes or no, why?
2. (If yes) Is there anyone or something that made you interested in science?
3. (If not) Is there someone or something that has discouraged you from science?
4. How important are careers that involve science? Why?
5. Are you interested in careers that involve science? Which one (s) attract you?
6. What do you think about the way that science is taught at school?
7. What do you think about learning science outside of school? How does this happen?
8. How do you think science education could be more attractive?

Section B: Questions about mathematics

1. Are you interested in mathematics? If yes or no, why?
2. (If yes) Is there anyone or something that made you interested in math?
3. (If not) Is there someone or something that has discouraged you from math?
4. How important are careers that involve mathematics? Why?
5. Are you interested in careers that involve math? Which one (s) attract you?
6. What do you think about the way that math is taught at school?
7. What do you think about learning math outside of school? How does this happen?
8. How do you think math education could be more attractive?

Section C: Questions about science and mathematics

1. Do you value more science or math? Why?
2. Are you more interested in science or mathematics? Why?

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Chapter 9 - Effects of Simulation-Based Physics Assessment on Students' Conceptual Understanding

Mihwa Park

Chapter Highlights

- Formative assessment happens formally as well as informally during instruction, and it is often seamlessly integrated into learning activities.
- College students still often hold misconceptions about force and motion even after they have learned the concept in an introductory physics class.
- Running computer simulations and observing a scientific event are beneficial for students in transforming their superficial and fragmented knowledge to be more structured and connected.
- When computer simulations are integrated into a formative assessment, students' normative explanations of the scientific event is improved.
- A simulation-based formative assessment is effective not only in diagnosing students' misconceptions about science, but also in facilitating their conceptual understanding of scientific ideas.

Introduction

The main purpose of formative assessment is to monitor students' progress during instruction in order to improve their learning outcomes. Formative assessment is often perceived and practiced as a type of assessment test; thus quizzes, short tests, or certain formative assessment techniques (e.g., card sorts, concept maps) are sometimes considered as possible formative assessments. However, teachers perform formative assessments informally as well as formally during their instruction, and they often seamlessly integrate formative assessments into learning activities. Thus there is no need to make a clear distinction between formative assessments and learning activities (Liu, 2010). Learning activities natually include both informal formative assessment activities—for example, assessment conversations (Duschl & Gitomer, 1997)—and formal formative assessment activities—for example, learning tasks or homework assignments.

Computer simulations have been acknowledged as useful in promoting students' engagement in observing and exploring scientific phenomena (Srisawasdi & Kroothkeaw, 2014) and in facilitating their conceptual changes (Rutten, van Joolingen, & ven der Veen, 2012; Trundle & Bell, 2010). In science instruction, computer simulations have been widely used, especially to provide students opportunities to experience what they cannot easily see or do in real life. For example, it is almost impossible to entirely remove or control frictional force in a traditonal physics lab setting. Computer simulations enable students to control frictional force in order to observe scientific phenomena in different situations. In addition, computer simulations are convenient; students can use them anywhere they can access and run them.

While many studies have been done using computer simulations as a main tool in designing learning tasks and found positive effects from using simulations on students' learning, there is still a lack of studies on how simulation-based formative assessments influence college students' understanding of fundamental physics concepts. This study explores the effects of a simulation-based formative assessment task on students' conceptual understanding of physics, especially focusing on force and motion in one dimension.

Computer Simulations in Teaching Science

The effects of using computer simulations in educational settings have been reported in many empirical studies. These include positive effects on student performance, motivation, and attitude (Rutten, van Joolingen, & van der Veen, 2012), and enhancing student content knowledge in science and facilatating their conceptual change (Smetana & Bell, 2012). Srisawasdi and Panjaburee (2015) conducted a quasi-experimental study to investigate simulation-based formative assessment effects on students ranging from 14 to 15 years old, and reported that when simulations were integrated into formative assessments, the students' understanding of scientific concepts was significantly improved. In science teaching, inquiry-based learning with computer simulations promises to promote students' conceptual change (Chen et al., 2013) and to develop their scientific understanding and explanations using scientific ideas (Srisawasdi & Panjaburee, 2015). Sarabando et al. (2014) found that computer simulations were even more effective in teaching students scientific concepts than hands-on activities. But despite the effectiveness of computer simulations in teaching and learning science, simulations alone are limited in their ability to make positive learning outcomes for students. In order to maximize the positive effects of computer simulations in fostering students' learning, teachers' role in integrating simulations into their instructions plays an important part (Waight et al., 2014). Thus, how teachers design learning activities integrating computer simulations is the most critical factor in cultivating the effect of simulations in teaching and learning science.

Student Conceptions About Force and Motion

Student conceptions about force and motion have been stuided intensively since the 1980s and 1990s. Many studies have reported students' common misconceptions about force and motion, which are listed in the following paragragh. In the current study, when we designed questions, we used those misconceptions to elicit students' normative and non-normative ideas.

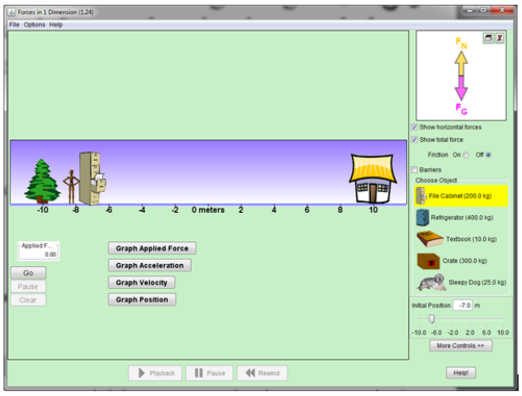
Previous studies on students' conceptions about force and motion found that students often confuse acceleration with speed and think that acceleration always occurs in a straight line. Some students think that large objects exert greater force than small objects, and that constant force results in constant speed (Chanpagne et al., 1980) or decreasing speed (AAAS Project 2061, n.d.). Some students also think that if no force is acting on an object, the object will slow down (Halloun & Hestenes, 1985), or that when an object's speed is descreasing, the force exerting the object to move forward must be decreasing as well (Clement, 1982; Watts

& Zylbersztajn, 1981). Some students think when a force acts on an object in the direction of the object's motion, the object's speed will stay the same for a while and then increase (AAAS Project 2061, n.d.). Additionally, students have great difficulty visualizing a frictionless situation (Halloun & Hestenes, 1985). Some students believe that when a force acts on a moving object in the opposite direction of the object's motion, the object will move at a constant speed (AAAS Project 2061, n.d.). Those misconceptions related to particular physics concepts are consistently found across diverse samples of students and adults (Eryilmaz, 1992). Teaching physics conceptually by providing discussion opportunities has a positive influence on student conceptual changes (Eryilmaz, 2002), but there is still a lack of studies on effectively eliciting students' misconceptions and promoting their understanding of those physics concepts. This study used computer simulations as an important component when designing a learning activity to reveal students' misconceptions (non-normative ideas) and to provide opportunities for them to interact with authentic physical situations so that they were able to connect what they observed to their scientific ideas.

Method

Simulation-Based Formatiave Assessment Task

A simulation-based formative assessment task on force and motion (see Appendix) was developed to investigate students' ideas and help their understanding of scientific concepts. Specifically, the task addressed a topic of force and motion in one dimension; it consisted of computer simulations and a series of two-tiered questions (a simple multiple-choice question and a justification question for which students wrote a justification for their answer to the multiple-choice question) and constructed-response questions. In total, 10 questions were included in the task. The computer simulation, Forces in 1 Dimension (https://phet.colorado.edu/en/simulation/legacy/forces-1d), was selected from PhET Simulations and embedded in the task. The task targeted students' conceptual understanding of physics, thus students were not asked to calculate any values or to demonstrate their mathematical competence. Specifically, the questions presented a scientific situation and asked students to predict what would happen; then the assessment asked them to run a simulation, posing questions that asked for explanation of the phenomena and comparison between their prior ideas and the observed phenomena. Figure 1 presents an example of a two-tiered question in the task.



1. Before you run the simulation, speculate what will happened to the cabinet's motion when a person is pushing it with little force (e.g., F= 5N) on a frictionless surface.
a. The cabinet will move
b. The cabinet will not move
c. More information is required

2. Explain the reason for your choice in the question 1 without using a formula.

Figure 1. Example Questions in the Simulation-Based Formative Assessment Task

Participants

Participating students were first-year college students who were taking an introductory physics course at a university in the United States. In total, 62 students voluntarily participated in the study and completed the task online after taking a lesson about force and motion in one dimension. In the study, students were not asked to report their gender or any demographic information.

Data Analysis

An analytic rubric for written responses was used to capture students' normative ideas (relevant scientific ideas), non-normative ideas (e.g., misconceptions), and off-task responses (see Table 1). During the process, two raters independently analyzed student responses and demonstrated a high inter-rater reliability (kappa coefficient > 0.8). After scoring student responses, the responses were categorized into four response models (see Table 2). For example, the mixed response model indicates when a student's response included both a non-normative idea(s) and a normative idea(s); the normative response model shows when a student's response included only a normative idea(s). The response models were subjected to analysis using descriptive statistics for each item to show how students' written responses changed before and after running the simulation.

Table 1. Analytic Rubric for Written Responses

Idea Types	Example Idea
Normative Idea	• When a net force is not zero, it results in an object's motion (velocity and acceleration). • When frictions cannot be ignored, the applied force should be greater than the frictional force to accelerate an object. • When a constant force acts on an object, the object's acceleration is constant. • When there is no force applied to a moving object, the object won't accelerate but keep its speed in a non-frictional situation.
Non-normative Idea	• A heavy object won't move when a force is applied in a non-frictional situation. • It will take time to increase an object's speed when a force is applied, and the object's speed will stay at the highest speed in a non-frictional situation. • A small force won't make an object move in a non-frictonal situation. • In order to keep an object's motion, an external force should act on the object continuously in a non-frictional situation. • When frictional force cannot be ignored, an object's speed will decrease regardless of the amount of applied force. • A contant force produce a contant speed. • Increasing speed requires increasing force. • A large object exerts a greater force. • When there is no force applied to an object, the object will slow down in a non-frictional situation. • When an applied force decreases, the object must slow down. • In a non-frictional situation, an object will continue to accelerate regardless of the applied force.
Off-task	• Repeats the question. • I don't know, I learned it from the class. • Off topic.

Table 2. Student Response Models

Model	Description
Off-topic response model	Off-topic response only
Non-normative response model	Non-normative idea(s) only
Mixed response model	Co-existence of normative and non-normative ideas
Normative response model	Normative idea(s) only

Results

Descriptive Analysis Results of Student Written Responses

Multiple choice questions were scored dichotomously (1 or 0), and student written responses were scored using the scoring rubric (see Table 1) then categorized into the four response models (see Table 2). After finalizing the categorization, scores were assigned to the response models: 0 for an Off-topic response model, 1 for a Non-normative response model, 2 for a Mixed response model, and 3 for a Normative response model. In total, 62 first-year college students completed the online formative assessment task. The total scores had a range of 8 to 24, a mean of 18.81, and SD = 3.46 (see Table 3). The distribution was not normal but moderately negatively skewed (skewness = -0.737; see Figure 2).

Table 3. Descriptive Statistics of Total Scores

Total N	Range	Min	Max	Mean	SD	Skewness
62	16	8	24	18.81	3.46	-.737

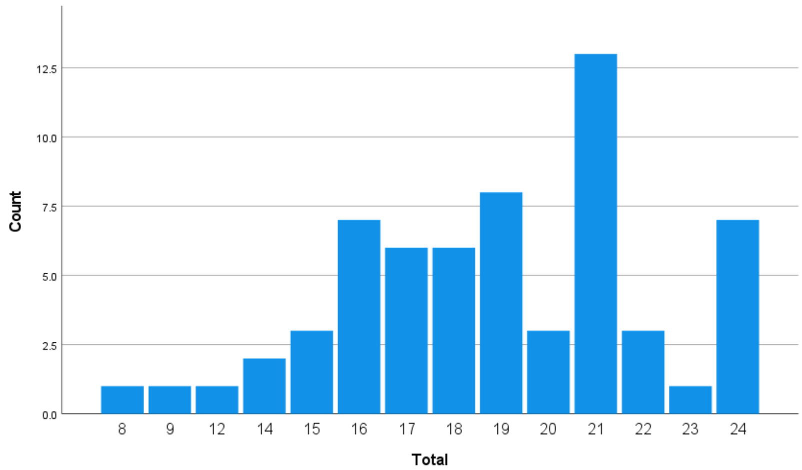


Figure 2. Bar Graph of Student Total Scores

After scoring all responses, student written responses were categorized into four response models as described earlier. Table 4 presents counts and percentages of the four student response models in each question. The task asked students to predict what would happen *before* running a simulation and to explain why it happened *after* running the simulation. Thus, it is indicated in Table 4 if a question was asked before or after running a simulation.

Table 4. Descriptive Statistics of Student Response Models

Before/After Simulation	Question	Number of Responses in Student Response Models (%)				
		Normative	Mixed	Non-normative	Off-Topic	Total
Before[1]	2	45 (72.6)	5 (8.1)	12 (19.4)	0 (0)	62
After[2]	3	47 (75.8)	3 (4.8)	11 (17.7)	1 (1.6)	62
Before	5	14 (22.6)	0 (0)	45 (72.6)	3 (4.8)	62
After	6	40 (64.5)	6 (9.7)	10 (16.1)	6 (9.7)	62
Before	8	52 (83.9)	1 (1.6)	7 (11.3)	2 (3.2)	62
After	9	55 (88.7)	1 (1.6)	2 (3.2)	4 (6.5)	62
Before	10	58 (93.5)	0 (0)	2 (3.2)	2 (3.2)	62

Note. 1. Before: Question was asked before running the simulation.
2. After: Question was asked after runnng the simulation.

The first set of questions (from Q1 to Q3; see Appendix) was developed for the situation that a person pushes a cabinet, exerting little force (5N) on a frictionless surface. Most of the students (> 70%) responded correctly even before running the simulation. When we compared numbers of non-normative responses and normative responses between before and after running the simulation, the number of normative responses had not changed much. Specifically, only two more responses were categorized into the normative response model after running the simulation, and one less non-normative response was found after running the simulation. The finding implied that the simulation was not very effective for helping students explain the particular situation normatively.

However, normative responses increased more than 40% when students were asked to consider a situation where friction cannot be ignored. To be more specific, the second set of questions (from Q4 to Q6) asked students to consider a situation where half of the track is frictionless and the rest of the track has friction. The students were asked to predict and explain how an object's (a cabinet's) velocity would change on the track where friction cannot be ignored. This set of questions was similar to the first set of questions, but with two differences—different surfaces (i.e., frictionless or frictional surface) and amount of exerted force (i.e., F = 5N in the first set of questions and F = 600N in the second set). The findings showed that 22.6% of students responded normatively before running the simulation, while 64.5% of students explained normatively why the cabinet's velocity changed after experiencing the simulation. The result indicated a positive effect from running the simulation on students' normative explanations of a scientific event in the particular situation.

The last set of questions (from Q7 to Q9) described a situation where a person pushed a cabinet and let it go on a frictionless surface. This set of questions was different from previous ones in that the force acted on the cabinet only in the beginning, while in the first and second sets of questions the external force was exerted continuously on the cabinet. Overall, more than 80% of students responded to the questions normatively in both before and after running the simulation. Three more cases were found in the normative response model and five fewer responses were found in the non-normative response model after running the simulation. The last question (Q10) asked students to predict what would happen after the person let the cabinet go where friction could not be ignored. In this situation, students gave the greatest number of normative responses (93.5%). This indicates that the effect of the computer simulation on students' conceptual understanding of motion in one dimension could be different based on specific situations.

Cases of Student Responses Becoming Normative from Non-normative

Further, student written responses were explored to see how their responses changed before and after running a simulation. In the case of the first set of questions, some student responses became normative after running the simulation. Below are some example responses.

> Student A:
> *Before running the simulation:* I don't think 5N is enough force to move a filing cabinet (non-normative model).
> *After running the simulation:* The cabinet did eventually move. I think this happened

because since there is no balancing force holding the cabinet in place or acting in the opposite direction there as a net force resulting in motion and then acceleration (normative model).

Student B:

Before running the simulation: If the weight of the cabinet is less than 5N the cabinet will move. If the weight is more than 5N the cabinet will not move (non-normative model).

After running the simulation: The cabinet moved very slowly. I think this was because there was no force of friction working against it so the cabinet was able to move even though it was being pushed with such small force (normative model).

These examples represent the cases where responses changed from non-normative to normative. Before running the simulation, those students' responses expressed a misconception (i.e., a small force won't make an object move in a non-frictonal situation). After running the simulation, the students responded normatively, using the scientific idea that there was no opposite force such as friction against the exerted force, and thus the exerted force could make the cabinet move. In this case, what they observed in the simulation was opposite to what they had predicted, and the experience helped them connect a scientific idea to what they had observed. Thus, the simulations were effective in helping students who held the typical misconception explain the scientific event normatively.

The second set of questions showed the biggest improvement in student responses—after running the simulation, 26 more students explained the scientific event normatively than before running the simulation. Some students' responses, showing the change from non-normative to normative, are presented below.

Student C:

Before running the simulation: When the cabinet reaches the frictional surface it will slow down because the force is acting against it (non-normative model).

After running the simulation: The velocity did not decrease but the rate of change decreased. The friction decreased the acceleration but it was not negative (normative model).

Student D:

Before running the simulation: Because the friction will be against the applied force thus lowering the acceleration which is going to lower the velocity (non-normative model).

After running the simulation: Because adding friction reduce the net force thus lowering the acceleration which lowered the slope of the velocity but did not decrease the velocity (normative model).

These example responses represent the cases where students' responses became normative after they experienced the simulation. In the non-normative responses, a misconception, *when friction cannot be ignored, an obejct's speed will decrease regardless of the amount of applied force*, was commonly found. After observing what actually happened in the simulation, students quickly used an acceleration idea and/or net force idea, and revised their responses to be normative. Since the participating students had learned the concept in their previous physics lessons, they already knew the concept of net force and the relationship between net force and acceleration. Thus, the simulation helped them to use the scientific concept when explaining the observed phenomenon. This also confirmed that students' misconceptions often reappear (Bransford et al., 1999) even after they have learned scientific concepts, and teachers thought that their misconception was replaced with scientific ideas.

The last set of questions showed the highest number of students who explained the scientific event normatively both before and after running the simulation. Although most of the students explained it normatively, there were still a few cases in which student responses changed from non-normative to normative.

Student E:

Before running the simulation: Since force causes the cabinet to accelerate even after letting go the cabinet's velocity will continue to increase with no interference (non-normative model).

After running the simulation: My prediction was wrong in that I stated that the velocity will continue to increase which was not correct in this case. After letting the cabinet go there remains no force acting on the body which causes the acceleration to go to zero. At that point velocity will remain constant and will not change until another force acts on it (normative model).

Student E's explanation after running the simulation again supported the previous finding that running a simulation helped students connect normative scientific ideas to what they observed. In summary, the simulation-based formative assessment task was implemented right after students learned the topic of force and motion in one dimension. Students' written explanations about scientific events showed that running simulations was effective in helping them apply what they had learned to the scientific phenomena.

Discussion

The purpose of this study was to explore the effects of a simulation-based formative assessment task on students' conceptual understanding of force and motion in one dimension. The task was developed and administered to first-year college students right after they learned the topic in their introductory physics class. In order to examine their understanding of the concept, students were asked to make a prediction about a scientific event and to explain why the scientific event happened. We found that the data distribution of students' total scores on the task was moderately negatively skewed. This is due to the fact that the students learned the concept just before they completed the task. Thus, overall the task seemed to be easy for the students.

When comparing students' written responses before and after running a simulation, overall the number of normative responses increased after running the simulation while the number of non-normative responses decreased. Note that we did not report cases in which students' responses changed to non-normative from normative, or cases in which their responses stayed non-normative after running the simulation, because in those cases it seemed that students had not followed the directions for running the simulation. Thus, those students might have observed a different scientific event. For instance, in the first set of questions, the simulation should demonstrate that a cabinet moves when a person is pushing it with 5N. However, those students whose responses changed to non-normative described that the cabinet did not move. This indicated that they did not follow the directions, and thus ended up observing a different scientific event. Thus, the simulation did not have a negative influence on students' conceptual understanding; rather, it was a simple mistake that those students did not run the simulation as they were instructed. As a conclusion, running a simulation helped students explain a scientific event more normatively. This finding is in accordance with previous studies (e.g., Chen et al., 2013; Smetana & Bell, 2012; Srisawasdi & Panjaburee, 2015) that computer simulations were effective for students' learning of science.

We also found that the effect of computer simulations was different depending on the situation where the scientific event occurred. When more students revealed misconceptions about a scientific situation, the effect of the computer simulation on students' learning was more positive. For example, many students' initial responses were non-normative in a scientific scenario involving both frictional and non-frictional situations. After running the simulation, their normative responses increased more than 40%. Whereas, when students were asked to consider situations such as a small amount of external force acting on an object or only temporary force acting on an object on a frictionless surface, most students' initial responses were normative. This implies that most students already had a normative understanding of the scientific concepts in those situations. Thus, the effect of the computer simulations was not noticeable. The last question (Q10) asked students to think about what would happen when they let a cabinet go after pushing it on a frictional surface. The result showed that more than 90% of students explained their predictions using normative scientific ideas. The question was similiar to Q5, which asked what would happen when a person pushed a cabinet on non-frictional and frictional surfaces. The number of students' normative responses to Q5 was the lowest out of all of the sets of questions, but the number of their normative responses to Q10 was the highest. Thus, this result confirmed the positive effectiveness of computer simulations on students' learning of science.

When a computer simulation was integrated into a formative assessment task, students had already learned the target scientific concept and topics when they attempted the task. Thus, the effect of using the simulation was different than it would have been if the simulation had been used to first teach the concept and topics. In the study, we found that students had typical misconceptions after they learned the concept in their physics class, and those misconceptions were effectively diagnosed when they were asked to explain their predictions about scientific events. This indicated that students still held misconceptions even after they learned scientific concepts in previous lessons. This result is not surprising, but it was noteworthy that their non-normative responses quickly became normative after they ran a simulation illustrating what actually happened in the situation. By running the simulation and observing what actually happened, students were able to connect a scientific idea with the observed phenomena and explain why it happened normatively. Thus, using computer simulations as formative assessment was effective in allowing students to enhance their knowledge and to provide opportunities to apply what they had learned to a real scientific situation. This finding implies that running computer simulations and observing a scientific event are beneficial for students to transform their superficial and fragmented knowledge to a more structured and connected one that could be applied to more authentic situations. This claim can be supported by the findings from students' responses to Q10, which showed the highest number of student normative responses. Running and oberserving simulations as a formative assessment facilitated students' learning, and its effect could be expanded to a similar but slightly different situation that could be explained with the same scientific concept. Thus, using computer simualations as a formative assessment is effective not only to diagnose students' misconceptions in science, but also to enhance their learning outcomes. Especially when students' misconceptions are dominant in a scientific situation, computer simulations can be an effective tool when integrated into a formative assessment to facilitate students' learning.

Conclusion

In this study, we examined how students' written responses were enhanced by running simulations. The findings showed that students benefitted by running computer simulations during their learning of science. More of their non-normative responses (i.e., misconceptions) became normative after they had run a computer simulation. Further, after running the computer simulations the students demonstrated that their scientific knowledge could be connected to what they had observed in the simulation. Thus a simulation-based formative assessment was effective not only in diagnosing students' misconceptions but also in facilitating their conceptual understanding of scientific ideas.

Recommendations

Integrating computer simulations into formative assessments is encouraged for use as a diagnostic tool to reveal students' misconceptions about science, as well as a teaching and learning tool to remedy those science. Thus, when designing formative assessment tasks, it is recommended to use computer simulations to provide students opportunities to experience scientific events and to connect their scientific ideas to observed phenomena.

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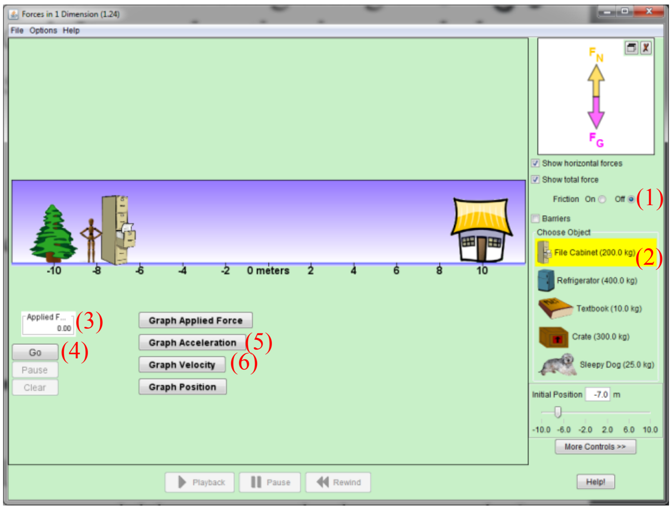
Appendix. Simulation-Based Formative Assessment Task on Force and Motion in One Dimension



1. Before you run the simulation, speculate what will happened to the cabinet's motion when a person is pushing it with little force (e.g., F= 5N) on a frictionless surface.

   a. The cabinet will move

   b. The cabinet will not move

   c. More information is required

2. Explain the reason for your choice in the Question 1 without using a formula.

**Now let's run the simulation. In the column on the right, choose (1) "Friction off", (2) "File cabinet", and on the left side, enter 5.00 in (3) "Applied F". Then click the (4) "Go" button.

3. Why do you think it happened the way it did? Please explain without using a formula.

4. Imagine a situation that we push the cabinet with F= 600N on the track. In the case, half of the track is frictionless and rest of the track has friction. Note that the static and sliding friction force are less than 600 N. Please speculate how the cabinet's velocity will change after passing the frictionless surface and traveling onto the surface with friction.

   a. The cabinet's velocity will Increase

   b. The cabinet's velocity will decrease

   c. The cabinet's velocity will remain constant

5. Please explain why without using a formula.

**Let's run the simulation. Reset the simulation by clicking the "Clear" button. Choose (1) "Friction off", (2) "File cabinet", and enter 600.00 in (3) "Applied F". Also choose (5) "Graph Acceleration" and (6) "Graph Velocity". Then click the "Go" (4) button. When the cabinet is passing around the middle of the window (around 0 meters), choose (1)"Friction on", and see what happens on the acceleration and velocity graphs.

6. Please explain why the cabinet's velocity changes as shown in the simulation using your ideas about force, acceleration, and velocity.

7. Now, we will apply force for only a second, then let the file cabinet go on a frictionless surface. Before running the simulation, please speculate what will happen to the cabinet's motion on a frictionless surface. After letting the file cabinet go, how does the cabinet's velocity change on the frictionless surface once the force stops being applied?

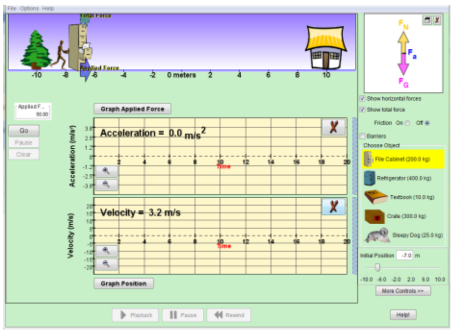
a. The cabinet's velocity increases

b. The cabinet's velocity decreases

c. The cabinet's velocity stays the same

8. Please explain why.

**Reset the simulation by clicking "Clear" button. Be sure to click the "Graph Acceleration", "Graph Velocity", and "Friction Off". Type "50" in the Applied F, then click "Go". When the cabinet passes the 0 meter mark (around the middle of the window), type 0 in the Applied F to change the applied force to zero. Watch the cabinet's motion, acceleration and velocity monitors.



9. why do you think it happened?

10. Let's assume that the surface has friction, and you applied 600N until it passes the middle of the window. What will happen to the cabinet's motion after you let it go? You can use scientific terms such as acceleration, velocity, energy, force and direction..

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For many years the need to educate and support our teachers to implement science and mathematics education has been ongoing throughout the world (National Academies of Sciences, Engineering, and Medicine, 2019; Mundry et al., 2009). In more recent years, this call has extended to include teaching through integrated science, technology, engineering, and mathematics (STEM) subjects as a vehicle to learn disciplinary core ideas, science and engineering practices, and cross-cutting concepts (NGSS Lead States, 2013). This book includes three sections: Learning Contexts in Teaching of STEM Disciplines, STEM Teacher Education, and Components Related to Students' STEM Learning Experiences. The first section of this book explores two unique contexts in which STEM education is being developed. The first chapter describes the current literature on the application of SocioScientific Issues to teach STEM in inclusive settings. The second chapter describes the development of public residential STEM High Schools in Egypt, completely reimagining how STEM is addressed in that country. The second section will explore aspects of teacher professional development in STEM as well as the motivations for teachers to learn and improve their STEM pedagogy. Specifically, the first chapter illuminates teachers' motivation and practices in STEM implementation. The second chapter describes the demands on and resources for STEM implementations for teachers and the effect these factors have on their job satisfaction. The third chapter in this section describes the analysis of video reflections and personal reflective accounts of a female preservice teacher, exploring self-efficacy, belonging, and identity in learning STEM content through the lens of gender. The final chapter also explores gender as a variable along with problem solving skills to explore the impact of these variables on STEM awareness levels of classroom teachers. These chapters illuminate challenges faced in preparing and developing STEM educators as well as the mindset and motivations of teachers in these fields. The last section dives into issues related to STEM learning experiences for students. The first chapter reports findings from a meta-analytic study investigating the relationship between self-efficacy and interest in a STEM career and the various student factors that influence this relationship. The second chapter analyzes the STEM identity from an international perspective. The final study investigates the effects of computer simulations on students' conceptual understanding of physics and scientific ideas.

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