“I Decided to Change the World”: A Case Study on Three Girls’ Perceived Abilities in STEM

by

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Chair of Examining Committee	Dr. Ann LeSage
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The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

ABSTRACT

This qualitative, case-study research is intended to contribute to the literature about the factors that influence young girls to envision themselves as individuals who are valued and capable in the realm of STEM. Through the implementation of maker pedagogies, this research addresses the question of how motivation, passion, and environmental factors (including the kinds of technology they interact with), impact the self-perception that three young girls have of their abilities in STEM, and in turn, their self-perceived STEM identity. This research took place over the course of a week, during a March Break camp, at Ontario Tech University's Faculty of Education. Findings suggest that throughout the week, as the participants engaged with 'making,' became more comfortable with their chosen 'deep-dive' technology and created their passion projects, they became more motivated in their abilities to create critically meaningful things with the Internet of Things (IoT). This increased motivation led to improved confidence to create with IoT, which ultimately, had a positive impact on their self-efficacy in STEM.

Keywords: STEM; girls; education; perceived abilities; Internet of Things; Makerspace; Maker Pedagogies

AUTHOR'S DECLARATION

I hereby declare that this thesis consists of original work which I have authored. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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The research work in this thesis was performed in compliance with the regulations of the UOIT Research Ethics Board (REB #15-094).

Laura Dobos

Laura A. Dobos

STATEMENT OF CONTRIBUTIONS

This master's thesis has foundations in a larger project that was funded by the SSHRC Canada Research Chairs (CRC) Program, entitled "Production Pedagogies" (with Dr. Janette Hughes as the principal investigator). The research in this thesis is a snapshot of this larger, longitudinal study; this study ran from March 11-15, 2019 (over the Ontario March Break).

The setting for this research was in Dr. Janette Hughes' STEAM 3D Maker Lab, in the Faculty of Education at Ontario Tech University. Through the mentorship of Dr. Hughes and the collaboration with lab research assistants, Jennifer Robb and Margie Lam, the camp was designed with a focus on Making, Citizenship and the Internet of Things (IoT). The importance of a personalized approach to learning was stressed in this research. The research design and methodology were informed by previous iterations of the camp, which guided researchers to implement assorted opportunities to make observations.

When intellectual materials or ideas that were not my own were used in this thesis, I employed standard referencing practices as outlined in the Publication Manual of the American Psychological Association, 7th Edition (American Psychological Association, 2020). Apart from these declarations, I declare that I am the sole author of this thesis and the sole source of the creative works described in this thesis.

ACKNOWLEDGEMENTS

It has been said that "a journey of a thousand miles begins with a single step" and there is nothing that could encapsulate the process of authoring this thesis more than this. The completion of this Master’s Thesis is something that I never thought I would see. The occurrence of the global COVID-19 pandemic nearly ended this process for me. With the support and encouragement of my family and friends though, I overcame the anxiety and fear that was caused by the pandemic. During this process, I lost my Grandpa Harrison. In the days that followed, my grandma told me a story about a conversation she had with him. In the months leading up to his passing, she mentioned to him that I was working on this thesis and his response was “that girl can do anything.” Those words will forever stay in my heart and were guiding lights for the hard days.

To my parents - thank you. You never gave up on me throughout this process. You handed down your work ethic, and I will be forever grateful that I have had you to look up to as I have grown. Without that, I would not be where I am today. The one thing that I always came back to was when mom asked me “How do you eat an elephant?” and when I gave her a confused look, she replied, “One bite at a time.” Every time I hit a wall, I thought back to that moment, and kept writing, to get this elephant eaten. You both pushed me to move beyond my comfort zone and continue to chase this dream and I have so much gratitude for your unwavering faith in my abilities.

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Finally, to the rest of my family and friends – thank you. It has been the greatest pleasure of my life, to build and nourish relationships with you all. You have all played a vital role in making me who I am today, and for that, I am forever grateful.

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LIST OF ABBREVIATIONS AND SYMBOLS

IoT	Internet of Things
STEM	Science, Technology, Engineering and Mathematics
EDI	Equity, Diversity and Inclusion
STEAM	Science, Technology, Engineering, Art and Mathematics
OECD	Organisation for Economic Co-operation and Development
ICT	Information and Communication Technologies
IBP	Inquiry-based pedagogies
SEI	Self-efficacy Index
URM	Underrepresented Minority
EI-ISB	Ego Identity Incomplete Sentence Bank
CAT	Concept Attainment Task
SEQ-F	Self-Esteem Questionnaire
SDT	Self-Determination Theory
CRC	Canada Research Chair
GTA	Greater Toronto Area
CCE	Climate Change Education
MSSES	Middle School Self-Efficacy Scale
GPA	Grade Point Average

Ladies if we want to rule the world – or even gain an equitable share of leadership positions – we need to stop leaning in. It's killing us. We need to fight for our right to lean back and put our feet up. – Rosa Brooks

Chapter 1. Introduction

An area of education that has received much attention over the last few years is students' engagement in Science, Technology, Engineering and Mathematics (STEM) education. The focus on STEM has developed from the increased need for highly skilled workers in these areas who can adapt to the changes in the labour market (Canada 2067, 2018). STEM education has proven to be essential for preparing students for this changing landscape of the labour market by teaching them global competencies, such as innovation, creativity and problem-solving (Hughes & Thompson, 2022). To engage students in STEM education, some teachers have introduced 'genius hour' (Robinson, 2018), 'hour of code' (MacIsaac, 2018), and robotics (Elkin et al., 2016), among other programs. Through the implementation of these programs, teachers aim to help students develop these global competencies (Elkin et al., 2016; Hughes & Thompson, 2022; MacIsaac, 2018; Robinson, 2018). Although preparing today's youth for future job markets is essential, a more pressing issue has arisen in light of all these changes – a lack of girls deciding to pursue STEM professions (Sharkawy, 2015).

Research in the STEM workforce has provided insight into the need for women in STEM professions (Hill et al., 2010; Reinking & Martin, 2018; Statistics Canada, 2015; Taz, 2017). For example, Statistics Canada (2021) reported that in the 2019/2020 academic year, 56% of postsecondary enrolments were women, but only 38.5% of students enrolled in STEM were women. Although most STEM subject areas need increased women representation (Casad et al., 2018), physics, mathematics, and engineering are in dire need (Taz, 2017). The concern about the shortage of women in the field stems from the vast number of untapped ideas and opinions from a female perspective.

Recently, because of the COVID-19 pandemic, Canadian societies have seen the impact that women in leadership roles can have on improving Canadians' lives. One specific example is Sunnybrook Health Science Centre's Samira Mubareka. In March 2020, Dr. Mubareka was part of a team which isolated the SARS-CoV-2 virus (Sunnybrook Health Sciences Centre: Congratulations Dr. Samira Mubareka, 2020) - a significant step in combatting the deadly virus. Women have been on the frontlines battling the virus throughout this outbreak, demonstrating a necessity for their voices in society -- STEM fields included. The Organisation for Economic Co-operation and Development (OECD) is a forum comprising 37 member countries, including Canada. OECD's 2020 COVID-19-focused publication outlined that "[w]omen are at the forefront of the battle against the pandemic as they make up almost 70% of the healthcare workforce, exposing them to greater risk of infection, while they are under-represented in leadership and decision-making processes in the healthcare sector" (p. 2). The lack of leadership roles for women in our society is concerning.

In addition to the need for the female perspective, the lack of women in STEM professions contributes to the gender wage gap seen in Canada (Leaper & Starr, 2019). STEM careers in today's society are the highest-paying, fastest-developing (Leaper & Starr, 2019; van Veelen et al., 2019) and the most in-demand jobs (Science, Technology and Innovation Council, 2015). Therefore, the lack of women in these positions has significantly contributed to gender inequality in salaries (Leaper & Starr, 2019).

Beyond the need to create equity between the gender wage gap, the lack of women in STEM has also contributed to global innovation performance concerns. For example, in 2015, the Science, Technology and Innovation Council released their *State of the Nation report*, which indicated that "Canada has fallen further behind comparator countries on key business innovation performance indicators, and the gap between Canada and the world's top five performers has widened" (p. 2). This concern coincides directly with a lack of STEM knowledge and skill in university graduates and, therefore, vacant job positions in the STEM workforce (Science, Technology and Innovation Council, 2015). Thus, increasing the number of women in STEM in Canada is necessary to make Canada more competitive in the global economy (Council of Canadian Academies, 2015).

In attempts to determine why there is a lack of women in STEM, a plethora of research has been published within the last decade (Bamberger, 2014; Buschor et al., 2014; Çakır et al., 2017; Chapman & Vivian, 2016; Casad et al., 2018; Falco & Summers, 2019; Hughes et al., 2021; Kim et al., 2018; Master & Meltzoff, 2016; Reinking & Martin, 2018; Sharkawy, 2015; Walton et al., 2015). This research identifies two main branches of the problem: the recruitment of women into STEM fields and the retention of women once they are in those fields (Ceci & Williams, 2010). Within the scope of recruitment, the three themes in the research include:

- STEM career stereotypes (Reinking & Martin, 2018)
- The lack of woman role models in STEM careers, and thus, limited sources of inspiration for girls to develop a STEM identity (Buschor et al., 2014)

- The importance of pedagogical approaches that educators use to foster passion and interest in STEM disciplines (Buschor et al., 2014; Reinking & Martin, 2018).

When considering retention of women in STEM fields, various experiences and reasons for the lack of retention have been cited (Castro & Collins, 2021; Lin & Deemer, 2021; Saucerman & Vasquez, 2014; Xu, 2017). Barriers because of parental leave and parental obligations were central to women leaving STEM professions (Fouad et al., 2017; Saucerman & Vasquez, 2014). Engineers Canada and Geoscientists Canada (2016) cited various obligations at home, a lack of guidance, stringent work hours, and the perception that STEM workplaces are unfriendly to women were all reasons women left their STEM profession. Most of these concerns (apart from the cold environment) relate to the traditional role of women in society. The role of women in society has a narrative often rooted in the 'homemaker' and 'caregiver' archetypes (McLean & Syed, 2015). Historically, women's identities have been shaped by the societal expectation that they should care more about family and child-rearing than men (Nicholson, 1997). Historically, women who dedicated more effort and time to their careers over their children were considered deviant (Erikson, 1964).

Structural changes in society, such as paid maternity leave, access to birth control, and the establishment of daycares, have been introduced to help shift the narrative of women; however, the historical implications still impact women in modern society (McLean & Syed, 2015). There is a battle between the narratives of doing what was traditionally acceptable (home-keeping) and shaping the future of women's narratives (joining the workforce) (McLean & Syed, 2015).

As much as one might want to turn a blind eye to the impact, these narratives inform women's identities, their perceived abilities in STEM, and, therefore, their ultimate choices in life. These choices include the profession they pursue and their willingness to balance the needs of their work and home lives. There is a need for women to form identities that are indicative of a changing societal landscape. Identity impacts the expectations of women in society and, therefore, plays a vital role in the retention of women in STEM professions.

Just as women's identities are a concern, an even more significant problem focuses on women of under-represented minorities -- women of colour, women with disabilities or those who identify as sexual minorities. Studies have shown that if all women are underrepresented in STEM, women in the aforementioned groups are even more so (Not all scientists are raised equal, 2017). An example of this is the awarding of Nobel prizes. Lunnemann et al. (2019) found that in "[t]he last 15 years ten women were honoured with the Nobel Prize within Physics, Chemistry, Economics, and Medicine and Physiology this is exactly the same as the first 100 years of the Nobel Prize's history" (p. 3). Meho's 2021 study reinforces the notion: "from 2001 to 2020 [the world's 141 most prestigious international research awards] were received 3,445 times by 2,011 men and 262 women" (p. 976). Beyond the fact that so few women have won these prestigious awards is the concern that as of 2017, "the Nobel prizes in the fields of physics and chemistry have been awarded to a total of 0 women of colour (out of 379 laureates)" (Not all scientists are raised equal, 2017, p. 1).

Girls need to know that it is acceptable to identify as a girl of colour, scientist, engineer, or astronomer. Women of colour are doing amazing things in STEM, but at this point in time, they are not recognized through the awarding of prestigious awards. As a result, girls do not see the impact of women who look like them. Groups in society must consider the influence of perceived gender abilities as they encourage girls to pursue careers in STEM.

1.1 Considerations

Efforts are being made to encourage girls to pursue STEM careers; however, there is still much work to be done (Reinking & Martin, 2018) at both the societal and institutional levels. One variable that impacts the recruitment of girls in STEM is how they explore STEM concepts in school, resulting from pedagogical approaches used by their STEM teachers. One variable to focus on is the vehicle used to guide the learning of STEM content for girls in the K-8 setting, is pedagogical approach alterations. Often for girls, there is a lack of interest and confidence in STEM subject areas, which develops early on in their educational careers and continues to increase as girls mature (Brottman & Moore, 2008; Shuen et al., 2011; Tai et al., 2006; Tan et al., 2013). This emphasizes the need for girls to develop an interest in STEM at a young age because a critical predictor for whether girls will pursue STEM careers is their interest in STEM as they go into secondary school (Sadler et al., 2012). The shortage of women who choose to pursue a career in STEM might be alleviated through the establishment of STEM teaching and learning approaches that keeps girls engaged and passionate about what they are learning. Although this will not solve the retention problem of women in STEM, it is undoubtedly a critical starting point.

The root of the above concern is how to approach teaching and learning in a way that keeps young girls engaged and passionate about STEM subject areas. Students today live in a highly mobile and technologically advanced society, and those factors dictate how they interact with people and navigate experiences (Wallace-Spurgin, 2020). Research on Information and Communication Technologies (ICT) has been conclusive in stating that technology keeps students engaged in their learning when implemented authentically by the educator (Attard & Northcote, 2011; Li, S. et al., 2017; McClure et al., 2011). Constructivist learning and makerspace pedagogies have been central to recent research on successful technology implementation practices (Geçu-Parmakisz et al., 2021; Hughes et al., 2022; Hughes et al., 2020; Hughes et al., 2019). When educators adopt these pedagogical approaches, student success indicators such as engagement and motivation are more easily observed (Maas & Hughes, 2020). For this reason, inquiry-based pedagogies were central to this project's planning and research design.

In addition to considering pedagogical approaches, the vehicle for technology delivery was also a central pillar for planning and implementing this research. For example, an emerging technology that might be an avenue for discovery is the Internet of Things (IoT). IoT is the network interconnection of everyday physical objects (Xia et al., 2012). The objects that humans interact with daily are being turned into digital input and output devices, capable of connecting to each other and humans in ways that have never been seen before (Xia et al., 2012). An example of the application of IoT is popular wearable technology, such as smartwatches. As an individual wears a smartwatch, the sensors take in information. With that input of data, the user receives analytical information from the watch that is used to better their life. Because of IoT's juxtaposition between STEM and personalized solutions for everyday problems, it might be a good vehicle for engaging girls in STEM.

The importance of IoT when it comes to engaging young girls is the capability for personalization and the opportunity it provides for users to create solutions for everyday problems (Yang et al., 2017). Personalization of STEM projects is one way that girls have demonstrated an increased engagement in STEM education (Gomoll et al., 2016). By exploiting this knowledge from previous research, it might be possible to determine promising practices for engaging girls in STEM education.

1.2 Research Goals

This ethnographic case study research aimed to understand how STEM self-efficacy is impacted for three girls aged 10-13 at a week-long March Break Camp. This immersive camp experience, entitled *Changemakers*, focused on the intersection of IoT and exploring social justice issues. This thesis aimed to investigate the shift (or lack thereof) of self-efficacy in STEM that each of the girls experienced through the exploration of IoT. Each participant's self-efficacy was then considered through their STEM identities. In this research, IoT acted as a vehicle for the girls to construct their knowledge of STEM concepts. In addition, this research was designed to allow the girls' passions to drive the use of the IoT.

Research questions focus on the question: How do self-perceived STEM identities shift for three girls, aged 10-13, from the beginning to the end of the Changemakers March Break Camp? Sub-Questions that were developed to help answer this question include:

- How might a week-long, immersive camp experience focused on inquiry-based making impact the development of a young girl's identity as it relates to self-perceived abilities in STEM?
- What, if any, impact does teaching STEM through the Internet of Things (IoT) have on a young girl's STEM identity?

Through data triangulation, including observations, tangible and digital artifacts, survey responses, open-ended interviews and focus-group interviews, a clearer picture was painted of inquiry-based learning and the IoT's impact on these girls' perceived STEM identities. In addition, James Marcia's Identity Status theory was utilized to guide a deductive content analysis methodology.

1.3 Statement of Intent

Having grown up in both the 20th and 21st centuries, my lived experiences as a millennial have allowed me to live a life before the innovation and growth that came with the vast expansion of technologies (I was a part of the generation that still learned cursive writing in school). My childhood was filled with activities that might be considered old-fashioned in today's society: exploration with my siblings and cousins in the forest behind our houses, VHS movies and dancing to tapes and CDs. However, as I grew, so did the readily available technologies to consumers. I remember the day that we got dial-up internet for our desktop computer; the excitement to go on MSN and talk to my friends who I had seen hours earlier at school was impalpable.

When I look back on those experiences, it is hard to comprehend how millennials have gone from being technologically inept to avid digital consumers in a matter of years. These individuals are critical pieces to the puzzle that is innovation in our society. That being said, women seem to have been left behind in these fields that drive innovation, which poses significant concerns for future advancement in STEM. Women provide different perspectives, lived experiences and ideas, which create greater opportunities for problem-solving and innovation.

This research aims to understand better the development of girls' STEM identities and the different technologies used to facilitate this development successfully. This knowledge can help increase the pipeline of girls going into postsecondary STEM studies and, ultimately, the number of women in STEM disciplines, contributing to innovation and the forward movement of our society.

Being a woman and a self-proclaimed *Steminist*, this research is near and dear to my heart. My passion for science and technology, alongside my desire to create equitable learning opportunities (and therefore career opportunities) for women and underrepresented minorities, have driven this research. Critical theory posits that "reality is shaped by social, political, and cultural events" (Creswell, 2016, p. 42), and this research is grounded in this idea. Creswell goes on to write that "[t]he rhetoric of research is shaped by social, political, and cultural norms in which the researcher seeks to address some of the power issues that affect oppressed individuals" (2016, p. 42). This aligns directly with the intention of this research. From a young age, I excelled in physical sciences and mathematics, likely because my father is a tradesman, and I saw the application of science and mathematics. As I moved through my education, my talent in those areas continued to progress, and I often considered a profession as a heart specialist/surgeon or an engineer. The stereotypes in the STEM field and fear of failure were my ultimate barriers to following those dreams. If possible, I want young girls to know that they are capable, worthy and, most importantly, *valuable* to the STEM fields. I hope this research will contribute to the body of research that is available to teachers and educational professionals. In reaching this targeted audience, they might gain the motivation to adapt their pedagogical approaches, so that young girls have more opportunities to explore STEM topics through their passions.

Chapter 2. Literature Review

With the rise of STEM education to address shifting needs in the work force, has come an accentuated gender discrepancy in those fields of work (Buschor et al., 2014; Reinking & Martin, 2018; Sharkawy, 2015; Walton et al., 2015). This gender gap is not new, and it has been the focus of a plethora of research over the years (Moss-Racusin et al., 2018; Reinking & Martin, 2018). It is often referred to as a "leaky pipeline" because it helps to describe how women essentially 'leak' out of STEM disciplines, as early as right after elementary school (Schmuck, 2016). In Canada, women earn one in five engineering and one in four computer science undergraduate degrees (Caranci et al., 2017). Governments have started taking notice of this problem, including Canada's then Minister of Science and Sport (July 18, 2018 – November 20, 2019), Kirsty Duncan, who announced in June 2018, a "made-in-Canada" approach to promoting equity, diversity and inclusion in STEM at Canadian educational institutions. This program is now called *Dimensions* and "addresses obstacles faced by, but not limited to, women, Indigenous Peoples, persons with disabilities, members of visible minorities/racialized groups, and members of LGBTQ2+ communities" (Government of Canada, 2019, para. 3). The program is in the pilot phase and includes 17 institutions from across Canada aiming to increase Equity, Diversity and Inclusion (EDI) across their campuses. These institutions will be among the first in Canada to be recognized for their progress in EDI research. This research will hopefully give critical insight into the need for EDI in professional workplaces (Government of Canada, 2019). Although the importance of women in the workplace needs to be considered, the foundation of this problem is in the girls that decide whether or not to pursue STEM professions.

This research is situated at the intersection of girls' identity development related to pursuance of learning STEM and the pedagogical approaches that can be used to promote young girls' interest in STEM. As such, the literature that has been reviewed includes research that focuses on the development of STEM identities and how they impact (or do not impact) the pursuance of future STEM endeavours. For the purposes of this literature review, the sections will be framed by these concepts:

- the impact of both external and internal factors on the development of a STEM identity and the consequential pursuance of STEM ventures
- factors that impact the avenues of exploration in STEM disciplines for young people

With a clearer understanding of the impact of each of these concepts, educators, policymakers and other stakeholders can make informed decisions about how to promote women representation in STEM careers. It is vital that the issue of the "leaky pipeline" (Blickenstaff, 2005), is addressed because when men and women work together to innovate and problem solve, a wider range of needs can be met. The diversity of ideas and opinions brought forward by different lived experiences creates rich opportunities to collaborate and undertake the complex problems currently facing our world.

This review will present the current published research within the realm of STEM identity, pursuance of STEM, women in STEM and factors that impact STEM identity development. Research literature focused on girls and women in STEM is growing rapidly, but because this area of research considers people and people are complex, there are gaps in current research. Following the presentation of current research, these gaps will be addressed. Finally, this chapter will conclude with a justification of where this current thesis is situated within the larger body of research.

2.1 STEM Identity and the Pursuance of STEM

The link between identity and abilities can be clearly identified through Marcia's Identity Status Theory, which is outlined thoroughly in the Theoretical Framework of this thesis. Marcia's theory postulates that identity is not static, and it is formed through the exploration of values, beliefs and goals, which ultimately lead to a commitment to these factors (Marcia, 1980). A STEM identity then can be considered "the extent to which people perceive their identity as a woman or man to fit with their identity as a STEM member" (González-Pérez et al., 2020, p. 4).

Research in this area spans back to when the theory was proposed. This theory, as indicated earlier, includes the categorization of individuals into different Identity Profiles: identity achievement, moratorium, foreclosure and identity diffusion. Identity achievement includes individuals who have explored and as a result, have committed to a profile that aligns with their beliefs and goals. The moratorium includes individuals who have actively explored their identity but have not committed to it. Those in foreclosure have not explored aspects of their identity, yet have committed to it. Finally, individuals who fall under the Identity diffusion category have not started to explore their identity, nor have they committed to it.

Inceptive research that focuses on women indicates that there is not a significant difference when it comes to intelligence between the four identity profiles (identity achievement, moratorium, foreclosure and identity diffusion), however, there are characteristics within each of the profiles that are noteworthy. Marcia and Friedman conducted research in this area (1970), with the goal of shedding light on how these profiles can be categorized for women.

The women in this study participated in semi-structured interviews that evaluated the presence or absence of decision-making ability, and their commitment to three areas: occupation, ideology (both religious and political), and standards of sexual behaviour. From there, the women were categorized into the different Identity profiles. After the women were categorized, researchers administered a number of tests in an attempt to find commonalities within and between profiles (table 2.1).

Table 2.1
Tests administered and researcher's focus - Marcia and Friedman, 1970

Test	Focus
Luchins' Water Jars Test	Cognitive Efficiency and Flexibility - The difference between the time it took to solve problem 7, from the mean time it took to solve 1-6 - Mean time to complete all 9 questions
Shipley-Hartford Vocabulary Scale	Intelligence - 40 item vocabulary recognition task
de Charms and Rosenbaum self-esteem questionnaire	Self-Esteem - 20 item self-esteem questionnaire
California F scale	Authoritarianism - Subjects indicate their level of endorsement of statements reflecting both authoritarian and democratic stances
Welsch Anxiety Scale	Anxiety or general maladjustment - a self-report anxiety scale used to assess anxiety

As previously mentioned, there was no significant difference between the profiles and intelligence. There were differences found in each of the areas studied:

- Self-esteem was highest in those who are in Foreclosure, and the lowest in those in Moratorium; notably, Identity Achievement also scored low in this section
- Authoritarianism scores also showed a significant difference between groups. Individuals in Foreclosure scored the highest and those in Moratorium scored the lowest.
- Anxiety scores were significant because unlike the other tests, individuals in Foreclosure scored the lowest and individuals in Identity Diffusion scored the highest.

Most interestingly though, research indicates that the individuals in each profile made different career pursuits. Those women in Identity Achievement and Foreclosure chose the most difficult college majors (which included Engineering, Chemistry, Biology, Mathematics and Pharmacy), while women in Identity Diffusion and Moratorium chose the least difficult college majors (which included Business Administration, Sociology, Anthropology, Education and Physical Education) (Marcia & Friedman, 1970; Matteson, 1974). The most difficult majors fall into STEM disciplines, whereas the majors that were deemed 'easy' are not categorized into STEM.

The identification of these commonalities within and between the profiles creates a jumping-off point for other studies to gain more insight into the profiles. In 1974, Matteson, a Danish researcher, conducted a similar study and his findings were congruent with those of Marcia and Friedman (1970).

Findings from Stitt Richardson et al. (2019) are mirrored by the findings of Marcia and Friedman, from over fifty years ago. The purpose of Stitt Richardson et al.'s 2019 study was to determine which ego identity status Black women in Engineering degrees occupy. The study took place at a university in the Southern United States and researchers utilized the snowball sampling method, which is outlined by participants recruiting additional participants (Ezzy, 2002). From this sampling method, nine Black women who were studying engineering in their undergraduate degrees were chosen to participate. To collect data, researchers utilized the qualitative methodology of narrative inquiry, which "utilizes individuals' written and spoken stories to provide their perspectives" (Stitt Richardson et al., 2019, p. 285). Semi-structured life history interviews were conducted in order to obtain the participants' lived stories. Questions were utilized to help participants focus on a specific topic: "their journey to engineering degree attainment" (Stitt Richardson et al., 2019, p. 285).

Following data collection, Stitt Richardson et al. (2019) used elements of thematic analysis in order to determine which identity status each participant occupied. Some of the codes that researchers looked for included: whether the participants researched and considered other majors, whether the participants committed to engineering as a career, whether participants were easily overwhelmed and if they had a strong sense of self. The findings of this research indicate that all the participants were committed to pursuing engineering occupations (therefore, must be in either identity achievement or foreclosure). As a result of this, the participants' exploration was more closely considered as researchers placed each participant into one of those two categories. From this, it was determined that the majority of participants (6 out of 9) occupied Identity Achievement and therefore had participated in ample exploration, which had informed their decision to pursue engineering. The minority of participants (3 of 9) occupied Identity Foreclosure, which is indicative of someone who has committed to pursuing a career in engineering, but with little to no exploration.

The findings of this study are significant, because "[u]ltimately, all nine Black women [who were in engineering degrees] were committed to engineering, which is an important finding because having an identity that reflects a commitment to science leads to a higher likelihood of persistence in STEM" (Stitt Richardson et al., 2019, p. 291). Additionally outlined is the significance of those participants that occupied Identity Foreclosure. Stitt Richardson et al. give two possible explanations as to why participants occupy this status:

- "[P]articipants chose engineering based on parental or teacher suggestion or because they chose to follow their parents' occupational choices" (2019, p. 291)
- "[P]articipants had high self-esteem, which is denoted by the high expectations they set for themselves" (2019, p. 291)

From their findings, Stitt Richardson et al. (2019) outlined three factors that impact participants' ego identity status, which include the importance of early exposure to STEM fields, the importance of an interest in mathematics and science emerging before enrolling in university, and the importance of teacher and parental support and suggestion.

The studies mentioned in this section demonstrate how multifaceted STEM identity is and together, they add strength to the argument that the presence (or absence) of aspects of STEM in one's identity can impact a woman's career trajectory. In order to fully comprehend the formation of one's identity (and therefore, their STEM identity), it is critical to consider the various factors that can inform one's identity. The following subsections will explore the impact of various factors (both external and internal), on the development of a woman's STEM identity.

2.1.1 External Factors that Impact STEM Identity

In order to understand the ways in which various factors impact the development of a girl's STEM identity, the various factors must first be defined. For this thesis, the definition outlined by Simpson and Bouhafa (2020) will be used to guide what is considered an external factor. Simpson and Bouhafa (2020) define external as environmental determinants, which included "GPA [grade point average], mentorship, environmental and classroom changes, educators … gendered and racialized discourses, social status" (p. 183).

These factors have been used as a guide, to help push forward the understanding of external factors in the context of this thesis. As such, external factors considered in this thesis include: stereotypes in STEM disciplines, women role models in STEM and family connections to STEM. Following these sections, the internal factors that impact a STEM identity will be explored.

2.1.1.1 Stereotypes in STEM disciplines

A common activity that researchers employ when investigating preconceptions in STEM involves asking students to draw what they believe a scientist looks like (Chambers, 1983). Chambers had teachers ask their students to "draw a picture of a scientist," over the span of 11 years, from 1966-1977. From the analysis of the drawings, two findings stand out that inform this thesis: only girls drew women scientists (girls made up 49% of the sample) and of the whole sample (4807 students), only 28 women scientists were drawn - 0.58% of the sample who drew a woman. The bleak findings from this study verified the stereotypical societal belief of the time: that scientists are men (Chambers, 1983). Societal stereotypes contribute to a lowered ability for women to identify with STEM, and results in a decreased motivation to pursue careers in these fields (Reinking & Martin, 2018; Steinke, 2017; Starr, 2018).

Through their summative content analysis of current literature surrounding the gender gap in STEM, Reinking and Martin (2018) defined stereotypes in STEM as one of the main factors for the observed gender gap. They used three guiding questions to approach their content analysis:

- What theories describe and explain the phenomenon of the gender gap in STEM fields?
- What strategies or ideas are available for girls to engage in STEM concepts?
- How can educators assist in closing the gender gap in STEM fields?

Following the collection of research articles, three themes emerged:

- The theories describing why there is a gender gap in STEM.
- Movements and strategies to engage girls in STEM.
- How educators can engage students as a way to close the gender gap in STEM.

These three themes were then broken down into big ideas within the theme. Findings indicate that there are three major theories that have been linked to the numerical discrepancy of girls in STEM. The first of these theories is Gendered Socialization, which connects directly to societal gender norms and how they dictate the way that boys and girls are socialized. In their research, Reinking and Martin (2018) determined that gendered stereotypes begin at a young age and “these gendered stereotypes shape girls’ math attitudes and ultimately diminish their interest in STEM fields” (p. 149). In addition to the Gendered Socialization theory is the theory of Peer Groups. This is the belief that peers have a great influence on one another and when an individual is successful in something, they gain support from their peers -- this is positive feedback. However, when one is unsuccessful, they receive negative feedback. Adolescents rely on their peers to determine what is deemed ‘cool’ or ‘uncool.’ This means that when fewer girls show an interest in STEM there is an almost ‘herd mentality’ that results in fewer girls choosing to engage in STEM. The final theory that is outlined is Stereotypes of STEM Professionals. The stereotypes that are outlined include the idea that STEM fields are male-dominated and social isolation is inevitable within STEM careers (Reinking & Martin, 2018). The ability for women to identify themselves situated in STEM professions is blunted by these external factors.

These findings are echoed by Steinke (2017), who focused on girls and the development of their STEM identities and also found that the impact of STEM stereotypes is impactful on young girls. Steinke states that “[p]opular media have played a crucial role in the construction, representation, reproduction, and transmission of stereotypes of STEM professionals” (2017, p. 716). The way that STEM professionals (scientists, engineers, technologists) are represented in media, through shows such as *The Big Bang Theory*, has major impacts on young girls and their motivation to pursue careers in STEM. STEM professionals are often portrayed as crazy, villains or loners, who are more often than not men (Steinke, 2017). Although attempts have been made to increase the equity and representation of women in mainstream STEM media, the work of women in these representations is often undermined and overlooked (Steinke, 2017). These images that young girls see in the media impact their STEM identities (Steinke, 2017), which ultimately impact their future decisions (Janarthanam & Gnanadevan, 2014).

The stereotypes that are demonstrated in the media often mirror those of the real world. Starr (2018) determined that "implicit gender-STEM associations may directly affect women's motivation to enter STEM careers and the value they place on STEM, independent of STEM identity" (p. 498). Her research focused on two research questions:

- Would stereotyping STEM as a domain for nerdy geniuses negatively relate to women's STEM identity?
- Would STEM identity mediate the relation between stereotypes and STEM motivation?

To answer these questions, Starr recruited 195 undergraduate students to participate in the study, and a survey was used to collect data. Each participant completed the same tasks, focused on five concepts: implicit associations about STEM and gender, explicit associations about STEM and gender, nerd-genius STEM stereotypes, STEM identity, STEM expectancy and value beliefs and STEM career motivation. A number of key findings arose from their study, including:

- STEM identity significantly mediated the relation between the above stereotypes and STEM motivation
- Endorsing stereotypes that people who work in STEM are nerdy geniuses who are tech obsessed, have no social lives, and are not successful romantically was negatively related to STEM identity
- The more women explicitly associated STEM with men, the lower their identification with people in STEM was

These findings align with those of Reinking and Martin (2018) and Steinke (2017), who both outline the role that STEM stereotypes play in a woman's decision to pursue STEM careers. Stereotypes that dictate the 'norm' for individuals who work in STEM professions, have been detrimental in the recruitment and retention of women in STEM. STEM stereotypes have an impact on the ability for women to identify with STEM professions, and in turn, women often feel unmotivated to pursue STEM careers.

In addition to these bodies of work, Kim et al., (2018) compiled a systematic review of empirical research that focused on STEM experiences for girls, during middle and high school. Their review was guided by the search for "specific psychological factors relevant for identity development that are connected with STEM success and failure in female students" (p. 594). The questions that paved the way to understanding these factors included:

- What kind of STEM environments do young women experience in middle school and high school?
- What efforts have been made to bring about change in the STEM environment young women experience?
- Have there been efforts to change the prototypes of STEM identity?
- What implications and recommendations for theory, research, programs, and policy emerge from investigating the literature from a social identity perspective?

To answer these questions, nine databases (Education Databases, ERIC, EthnicWatch, GenderWatch, Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) database, PsychArticles, PsycINFO, Psychology Database, and Social Science Database) were used to search for research that reported STEM experiences of women, over the past 10 years. Key words that were searched included "'STEM' and science OR technology OR engineering OR mathematics … motivation, interest, attitudes, sense of belonging, self-concept, self-esteem, and self-confidence … [as well as] [d]ifferent variations of 'girls,' 'female,' and 'gender'" (Kim et al., 2018, p. 595). After exclusion criteria were considered, the authors reviewed 47 articles and their findings further support the implications that stereotypes impact women choosing to pursue STEM careers. The majority of research studies included in this review outline the negative stereotypes in the STEM environment, which advance the line of thought that women cannot be successful in STEM.

Within Kim et al.'s 2018 review, is the work of Brown and Leaper (2010), and Rice et al., (2013), who report on the negative stereotypes that are prompted by individuals in the young woman's environment. These stereotypes involve the belief that girls are not as good as boys in math, science and computers (Brown & Leaper, 2010) and that STEM disciplines are masculine (Rice et al., 2013). An added layer of complexity is introduced when the individuals who choose to look past the stereotypes created by society, are met with the stark reality that "the STEM environment [tends] to be narrow in the kind of woman that can be considered as part of the ingroup" (Kim et al., 2018, p. 605). Ultimately, the findings of Kim et al. indicate that young women do not feel confident in their abilities nor their potential for success in STEM disciplines. These feelings of uncertainty come from more than one source, the first being the stereotypes that are connected to STEM disciplines and the second being the negative signals that arise due to the social environments within which girls participate in STEM. This research verifies that young women are living in environments where parents, and other important figures in their lives, dissuade them from pursuing careers in STEM as a result of stereotypes (Kim et al., 2018).

The studies that have been explored in this section, outline the importance of addressing STEM stereotypes, in the crusade to create equity and promote diversity within the STEM disciplines. Stereotypes make it difficult for women to envision themselves as STEM professionals, which ultimately impacts their identities and therefore, their choice to pursue careers within STEM disciplines. The unfortunate reality is that through the reinforcement of these stereotypes, women continue to be dissuaded to join STEM disciplines. However, in an attempt to challenge the stereotypical norms that have been outlined, it is important to consider how girls are impacted by an alternative view of STEM; one that considers the inclusion and celebration of women.

2.1.1.2 The Impact of Women Role Models in STEM

Recently, women in STEM, from organizations such as Girls Inc., Engineer Girl and LEGO have recognized their impact and have started to take action (Reinking & Martin, 2018). These organizations have taken different approaches to achieve the same goal of encouraging girls to pursue STEM careers (Reinking & Martin, 2018). As previously outlined, Reinking and Martin (2018) utilized a summative content analysis methodology, to gain insight into theories related to the gender gap seen in STEM, as well as strategies to engage young girls in STEM.

In addition to the aforementioned findings that indicate how stereotypes negatively impact a woman's ability to situate herself within a STEM identity, Reinking and Martin (2018) also found that when girls had a positive, woman STEM role model, their interest in STEM increased. Through exposure to stories, pictures and conversations with women in STEM, the girls were more able to see themselves in STEM-related roles and this meant an increase in the girls' positivity towards STEM subjects (Reinking & Martin, 2018).

Echoing this concept, Buschor et al.'s 2014 longitudinal, mixed methods study aimed to determine whether academic high school girls, who intended to study STEM, actually enrolled in these studies two years later. This study also took into account the participants' experiences, retrospectively once they were in their chosen discipline. To guide this study, the following research questions were used:

- To what extent are the female students who intend to choose STEM at the end of academic high school persistent in their choice 2 years later?
- What factors play a role in women's choice of a STEM major rather than one in social sciences or humanities?
- How did women studying STEM perceive the process of choosing a major retrospectively?

The research took into account 843 participants, all of whom were girls from German-speaking high schools in Switzerland. Buschor et al.'s study utilized a longitudinal approach to accommodate for the milestones in the Swiss education system. The first milestone that was of focus for this study was six months before finishing academic high school. At this point, participants completed a questionnaire that focused on their career options. The second milestone was two years later (participants were in university at this point) and participants were asked to complete another questionnaire which focused on their actual choice of university major. In both these questionnaires, the following factors were considered: competence in mathematics and German, study profile, university major, support from the father, gender stereotypes related to mathematics and study and job-related expectancies.

The quantitative findings of this study indicate that of the girls who stated that they wanted to pursue undergraduate degrees in STEM fields, 86% followed through with this intention. The qualitative analysis shed light on the factors that impacted the experiences of the participants. The main themes that arose were: the importance of early sense of identity as a future scientist, the need for emotional and learning support (mostly from parents), the influence of role models in the broader network (friends or neighbours working in or studying STEM), parental concern (parents feared that STEM would overstrain their daughter), mathematics as a means to an end (not necessarily a skill that can contribute to their success), a sense of uniqueness (with regards to being in STEM -- women are few and far between and participants liked being 'special'), a broad range of interest and minimizing risks and optimizing profit (students aimed to choose a major relating to a clear career).

Most interesting among the findings, is the importance of dissociated role models in STEM. Participants did not so much look to family members as role models, but rather to individuals who were in their broader network, such as family friends. The theme emerged from the narratives of 11 female STEM students, who indicated that role models (including role models from social media) played an important part in the participant's decision to pursue STEM careers (Buschor et al., 2014). These individuals served as "[either] a source of information or supported the women during their decision-making process" (p. 172). The importance of this comment lies in the formation of identity through Marcia's Identity statuses (1980). Identity Moratorium and Identity Affirmation both require the individual to partake in exploration, as they form their identity. In Buschor et al.'s (2014) study, the exploration of the participants was supported by a role model within the participant's broad network, and that had implications within the participant's motivation to actively continue to pursue STEM careers. Buschor et al. (2014) did not focus on the environment or context in which the role model interacted with the participant, nor did they indicate the sex of the role model. Bamberger (2014) however, did focus on the environment of the mentorship and interestingly, determined contradictory findings.

Bamberger's (2014) mixed-methods study aimed to answer two research questions:

- What are the girl students' perceptions of women scientists and engineers, their own capability of dealing with STEM, and their tendency to choose a future STEM career?
- How and to what extent are these perceptions changed following visits in a high-tech company and meeting with women scientists and engineers?

The study was conducted in one of the largest technology companies in Israel. This specific company offered a mentorship program for girls from local areas. The program provided the opportunity for "the students [to meet] with women scientists and engineers [from] the company" (Bamberger, 2014, p. 552) and visit the company, through class-visits. Twelve women employees of the company (most of whom held a PhD in science or engineering), participated in the mentorship program.

The researchers broke up 90 participants into an experimental group that consisted of 60 of the school girls, and a control group that was made up of 30 of the school girls.

After exclusion criteria, the experimental group had 36 participants and the control group had 26. The experimental group met with women scientists and engineers from a local company, who acted as role models for these young girls, while the control group did not (Bamberger, 2014). When the experiment group met with the mentors, it was noted that:

> Every woman scientist who guided a session in the visits introduced herself and described her path of choosing a profession. They talked about difficulties and challenges that emerged from being a woman in a masculine setting. The women scientists encouraged non-formal discussions regarding inequitable gender relations, satisfaction, and family-work balance. (p. 552)

The same questionnaire was given to the participants before the study began and after the study ended. The focus of the questionnaire was to gain insight into participant's backgrounds, their perceptions of women in STEM, their self-perceived abilities when it came to working in STEM in their future, their major study topic and career aspirations. In addition to the questionnaires, girl-only focus group activities were conducted. In groups of 6-8, participants were shown one of three decks of cards, which focused on participant's perceptions of women scientists and engineers, participant's capability of dealing with STEM, or participant's future career choice. The cards had varying statements, and the girls were required to choose the card that most closely aligned with their beliefs in the area.

Although the aim of the intervention was to encourage young girls to pursue careers in STEM, Bamberger (2014) found that the girls who met with the women scientists and engineers reported feeling fearful, fewer perceived woman scientists and engineers in a positive way, more girls felt that they could not be successful in STEM and fewer girls chose STEM as a major study. This study reinforced the findings from Lightbody et al. (1996) which indicates that girl's perception on a STEM ability aligns with the belief that 'we can, I can't.' Bamberger's (2014) results contradict a large body of literature, which states that having a woman role model in STEM is a predictive factor for young girls going into STEM professions (Buschor et al., 2014; Casad et al., 2018; Master & Meltzoff, 2016; Sharkawy, 2015; Van Camp et al., 2019). However, Bamberger does outline some factors that were overlooked, which may account for the discrepancy:

- a cognitive gap between the knowledge and understanding of the girls and the vocabulary that the scientists and engineers used
- a developmental gap between the participants (9th grade) and the scientists and engineers
- the lack of a foundational relationship between participants and the scientists and engineers; the role model wasn't considered a 'caring adult' for the participants
- The cultural context: all of the participants were girls who came from a modern-orthodox single-sex secondary school

It is very likely that these factors could have had major implications in the findings of this particular study. Within the body of literature that is available on this topic, majority asserts that central to interventions that are based on role-models, is the concept of belonging and a sense of identity within STEM (Casad et al., 2018; Van Camp et al., 2019). This kind of mentorship requires personal connections between the girls and the STEM community (Casad et al., 2018; Van Camp et al., 2019).

To reinforce this stance, González-Pérez et al. (2020), conducted a study that was specifically designed to foster the relationship between the young girls participating, and the STEM professional. It was noted that within the experimental design, González-Pérez et al. implemented the use of:

> actual STEM role-model women who are physically present in the classroom and who are talking in first-person terms about their own lives and professional experiences to young girls at a decisive stage of their lives (preadolescence), which is precisely when they start to consider dropping out from these disciplines because their individual self- efficacy is in flux. (2020, p. 2)

This study implemented multigroup structural equation modeling analysis. Participants (aged 12-16) were asked to complete two questionnaires. The first was completed one week before the mentoring intervention began, and the other was administered one month after the mentoring began. Data were collected using a variation of the expectancy–value questionnaire (EVQ) (Eccles & Wigfield, 1995), and participants were asked to rate statements on a Likert scale of 1-7 where 1 indicated "strongly disagree" and 7 "strongly agree"). There were seven main concepts that the questions centered on: gender stereotypes about math abilities, expectations of math success, math enjoyment, importance attached to math, STEM career choice, STEM counter stereotypical content of the sessions and construct validity.

The findings of this research coincide with those of Buschor et al. (2014). The results demonstrate, that on average, the role-model intervention has a positive and significant impact on math enjoyment, the importance that girls attach to math, expectations in math and expectations of success in STEM. This study, however, went beyond that and considered the impact of countersterotypical content (such as the importance of teamwork, social skills and communication, in STEM) within the mentor sessions. It was found that the greater the counterstereotyical content, the greater the relationship between math expectations and the choice to go into STEM. This result echoes the importance of addressing STEM stereotypes, which was noted in the previous section (2.1.1.1 Stereotypes in STEM disciplines).

The research in this area leaves some room for ambiguity when it comes to the impact of a woman role model in the lives of girls who choose to pursue STEM. However, the research is consistent in the understanding that in order for a role model to be a predictor of success for girls in STEM, the relationship must be established to create the dynamic of a caring adult, so that girls feel like they can identify with their role model.

This factor is tricky, because of the lack of women within STEM – it is a vicious cycle. There are few women in STEM, so there are few mentors who can help young girls feel a sense of identity in STEM, so fewer girls pursue STEM.

2.1.2 Internal Factors that impact STEM identity

In addition to the external factors that impact a woman's STEM identity, the internal factors need to be considered. The definition of internal factors was also influenced by the definition determined by Simpson and Bouhafa (2020). Internal factors include those which contribute to the "characteristics of the person" (p. 169), and include "recognition, interest, sense of belonging, and confidence" (p. 183). The various internal factors that will be central to this thesis include a passion for STEM and confidence as a result of self-efficacy in STEM.

2.1.2.1 Passion as a mediator for a STEM identity

Passion has been defined as "a strong inclination toward an activity that people love, that they find important, and in which they invest considerable time and energy" (Chichekian & Vallerand, 2022). This aligns with both Self-Determination Theory (SDT) and Marcia's Identity Statuses, in that individuals are motivated to explore their environments in order to grow as individuals. An important indicator of passion is it does not reflect a short-term interest, rather, it represents an integral part of one's identity (Chichekian & Vallerand, 2022). Building on this, identity is associated with persistence in the pursuance of goals (Smith et al. 2013; Thoman et al. 2014; Walton & Cohen, 2011), and as such, passion and persistence should be considered when determining factors that impact STEM identities.

Research on women and their passions leading them to careers within STEM disciplines is somewhat limited. However, there is a large body of work that relates to passion and career choices, in general (Rainey et al., 2018). Chichekian and Vallerand (2022) focused on the connection between passion and educational outcome. This research utilized two forms of passion: harmonious passion, which accounts for the fact that "one's passion is autonomously integrated into his or her identity" (Chichekian & Vallerand, 2022, p. 2), and obsessive passion, which relates to "one's passion [that] is internalized into the person's identity through external and internal pressures such as feelings of social acceptance and self-esteem contingencies toward the activity that they love" (Chichekian & Vallerand, 2022, p. 2). Aligned with these forms of passion, the authors associate different forms of persistence as factors that impact each type of passion. Flexible persistence is founded in harmonious passion and it allows for the individual to focus their desired goal, while also achieving goals in other areas of their life. Rigid persistence, however, is founded in obsessive passion and generally results in the achievement of a specific, narrowly focused goal. This often results in a lack of the attainment of other life outcomes.

Chichekian and Vallerand (2022) utilized a two-study approach, aimed to “test the role of passion for science as a determinant to the two types of persistence toward their goals in science” (p. 3). Study 1 consisted 591 participants from transitional colleges throughout Eastern Canada, whose ages ranged from 17-19. The intention of these transitional colleges is to prepare students for the path that they choose to pursue into the work force. Students have two choices: either a two-year preuniversity program (university bound students) or a three-year technical or career program (workforce bound). For this study, participants were all enrolled in preuniversity STEM programs.

Questionnaires were administered to each participant and data were analyzed using structural equation modelling, with the following four goals in mind:

- test the validity of a new persistence scale in education,
- test the associations between passion for and persistence in science,
- test the role of persistence in academic and wellbeing outcomes, and finally
- assess the mediating effect of persistence in the relationship between passion (OP and HP) for science and outcomes experienced inside and outside of school

To achieve this, participants were asked to rate statements about various concepts on a 5-point Likert scale, from 1 (totally disagree) to 5 (totally agree). The concepts that were considered in these questions included passion, the rigid and flexible persistence scale (how flexible or rigid the individual is when partaking in activities that are important to them), intentions, academic performance and psychological wellbeing. Following study 1, study 2 was completed, using the same process; however, participants were 196 students from second year college students (from the same colleges as study 1). The goals of study 2 were to test another mediator for academic-specific outcomes in STEM, in addition to extending the findings of study 1. The additional mediator was the involvement in extracurricular scientific activities.

Findings of this research indicate that both flexible and rigid persistence mediate the relationship between passion for science and academic performance. Ultimately, both of these persistence methods correlated with the individual pursuing STEM disciplines. The implications of this research are critical, as the impact that passion has on the pursuance of STEM disciplines could act as an entry point for girls.

Similarly, Ruiz-Alfonso and León (2017) aimed to determine the impact of a teacher's emphasis on usefulness of content, as it relates to student harmonious passion, intrinsic motivation to learn said content and achievement in the content area. The following hypotheses guided the research:

- Students perceive harmonious passion and motivation as two different constructs.
- Harmonious passion will be positively associated with math achievement.
- The relationship between passion and achievement will be mediated by motivation to learn.
- Teacher emphasis on class usefulness will predict students' harmonious passion.

An important differentiation that was made by the authors was where passion deviates from intrinsic motivation. Ruiz-Alfonso and León write that "passion and intrinsic motivation share the love for the activity and the engagement in it for pleasure … but the non-internalization of the activity into one's identity makes the difference" (2017, p. 285). This difference is critical in recognizing the progressing through the interaction stages of the students within this study.

Participants in Ruiz-Alfonso and León's study included 1557 students (778 girls, 766 boys, 12 not specified), from nine high schools in Gran Canaria, Spain. The participants ranged from the equivalent to grade 8 to 10 in Canada (reported as "second to fourth grades of secondary education" within the study). Following recruitment, participants completed demographic questionnaires, as well as questionnaires "with measures of harmonious passion, motivation to learn, and their teacher's emphasis on the usefulness of class content" (Ruiz-Alfonso & León, 2017, p. 287). Each of the scales utilized the 7-point Likert scale (1 = disagree completely, 7 = agree completely). Confirmatory factor analysis was performed on the various variables to ensure validity (McDonald, 1999). Values above 0.08 were considered indicators of reliability.

The following factors and associated methodologies were considered within the questionnaires:

- Harmonious Passion - Six items of the Passion Scale (Vallerand et al., 2003)
- Motivation to Learn - Four items of the Intrinsic Motivation toward Knowledge subscale, with a focus on STEM
- Teacher Emphasis on Usefulness of Class Content - Six items from the Teacher Emphasis on the Usefulness of Class Content scale (León et al., n.d.).

- Math Grades - Final course grades were coded using the following metric: A+: 10; A: 9.175; B+: 8.325; B: 7.5; B−: 6.675; C+: 5.825; C: 5; C−: 4.175; D +: 3.325; D: 2.5; D−: 1.675; F: 1

The findings of this research are consistent with that of Chichekian and Vallerand (2022), which emphasize the importance of passion in the realm of learning. More specifically, Ruiz-Alfonso and León (2017) found that students consider passion and motivation to be separate entities, which informs the other findings. It was also determined that at both the individual and the group levels, harmonious passion predicted math grades, and this relationship was mediated by motivation. Additionally, harmonious passion was also predicted by the teacher's emphasis on the usefulness of the class content (see Teacher Pedagogies).

These studies are critical in understanding the impact that passion has on the trajectory of students. Passion not only impacts pursuance of STEM, but also the motivation that one feels to engage in STEM. Ultimately, these factors impact one's academic performance in STEM, which has implications in their STEM identity.

2.1.2.2 Self-Efficacy as a mediator for a STEM identity

In line with the impact that passion for STEM has in STEM identity formation, there are also implications for identity formation when self-efficacy in STEM disciplines is considered. Self-efficacy is the belief (or confidence) in one's ability to succeed within a certain discipline or context (Bandura, 1978). An important link between low self-efficacy and identity lies in the aforementioned stereotypes that are present in STEM disciplines. Research has found that for women and under-represented minorities (URMs), stereotypes lower self-efficacy in STEM related activities (Hill et al., 2010).

Alternatively, a link between positive self-efficacy and STEM identity can be found in positive persuasions and learning experiences (Stout et al., 2011).

To address research gaps in this area, Falco and Summers (2019) conducted a study, with the intentions of "examin[ing] whether a small group intervention, that incorporates the four sources of self-efficacy while also addressing perceived barriers, including gender issues, in career development, is effective at improving the career decision self-efficacy and STEM self-efficacy for adolescent girls" (p. 65). The four sources that are mentioned, are directly connected to Bandura's Self-Efficacy Theory. These four sources are outlined as "interpretations of actual performances, vicarious (modeled) experiences, social (verbal) persuasion, and physiological indexes (emotional arousal)" (Falco & Summers, 2019, p. 64). Their study was conducted in Arizona, and consisted of 88 high school ages girls – 44 were in the treatment condition, 44 were control. The participants in the treatment condition were split up into three smaller groups, in order to deliver small group interventions. The participants were recruited for the program, knowing that it was focused on STEM career development. The implementation of the study was conducted over nine, 50-minute sessions which were "designed to improve career decision self-efficacy and STEM self-efficacy" (Falco & Summers, 2019, p. 67). The treatment groups participated in the intervention in the fall, and the control groups participated in the intervention in the spring.

To measure the outcomes, the Middle School Self-Efficacy Scale (MSSES; Fouad et al., 1997) was utilized. This scale implemented a 5-point Likert type scale (1 – strongly disagree, 5- strongly agree), and consisted of 46 response items, with two subscales which consisted of 24 items – 12 of which focused on career decision self-efficacy and 12 of which focused on STEM self-efficacy. This tool was administered to all participants before the intervention, upon immediate completion of the intervention and again three months following the intervention. Results from this study indicate that there was a significant increase in career and STEM self-efficacy when the MSSES was taken times 2 and 3 for the treatment group; this difference was not seen within the control group. This research validates the importance of having small group interventions, when considering the improvement of self-efficacy in STEM disciplines.

The importance of purposeful interventions for the improvement of self-efficacy in STEM is echoed by Condon and Wichowsky (2018). Their research intervention is "motivated by the theory that integrating STEM and civics can enhance student engagement in both areas" (p. 198). This research focused on self-efficacy at the intersection of STEM and citizenship by "addressing community and societal needs, developing teamwork and communication skills, and creating more scientifically literate citizens who are able to confront collective action challenges" (Condon & Wichowsky, 2018, p. 201).

This research is centered upon the citizen science model, which aims to bridge STEM learning and community mindedness, as it creates opportunities to "engage people in self-selected cooperative endeavors to address shared problems" (Triezenberg et al., 2012, p. 214). Condon and Wichowsky's (2018) research design utilized a curriculum called STEMhero, which "takes advantage of technology already in students' homes and schools—water, gas, and electric meters—to integrate science and civics lessons on natural resource management" (p. 204). STEMhero uses citizen science as a basis to challenge students to solve sustainability concerns within their homes or schools. It implements authentic inquiry (see section 2.2.1.2), to inspire students to solve these problems, using their STEM knowledge.

In this study, the participants used STEMhero by following three steps:

1. Participants learned how to read and record the water meters at their homes and daily, they recorded the readings, on a web-based application.
2. Participants learned how to model and analyze their data, guided by connections to and impacts on natural resources. In this step, participants were introduced to various efficiency behaviours and technologies that impact water consumption.
3. Participants conducted data-driven inquiries, which tested the impact of the efficiency behaviours and technologies, on their water consumptions.

Through this methodology, participants were exposed to both STEM learning (understandings of units, measurement, and technology systems) and civic learning (human impacts on the environment, the collective action problems and equity concerns posed by resource scarcity etc.). This research utilized randomized controlled trials, to determine the effectiveness of STEMhero interventions on STEM engagement and civic empowerment. All participants went to Catholic middle schools (n=13), and some schools were given the treatment protocol (implementation of STEMhero curriculum over 2.5 weeks), while the control groups did not implement STEMhero in their learning.

The group each school was a part of was predetermined, however, all teachers went to STEMhero in-services one month prior to the intervention. One week before the treatment groups implemented STEMhero, all participants (n = 551 students) were given a survey to gauge their baseline STEM and civic engagement. Interventions were then implemented in the treatment schools, as outlined above. Finally, one week after the intervention, both control and treatment groups were given a post-study survey.

Findings of this research indicate that participants within the treatment schools reported greater gains in STEM engagement. Qualitative data indicates teachers did report an increased enjoyment and excitement to learn STEM through the intervention however, when considering the quantitative data, the motivation to learn STEM was not significant between the control groups and treatment groups. Interestingly though, participants in the treatment schools did indicate that they were more likely to pursue STEM in high school. When efficacy of civic engagement is considered, findings indicate that there is a significant difference between control groups and treatment groups. Treatment groups reported a stronger sense of civic empowerment and higher amounts of environmental and civic efficacy (the feeling that they can make a change). Although Condon and Wichowsky (2018) did not exclusively report that STEM efficacy increased, they indicate an increase in environmental civic efficacy, which indirectly demonstrates STEM efficacy. In order to make a change (as with environmental civic efficacy), individuals must have a knowledge of, and be confident in their STEM abilities. However, future research on clear connections between STEM efficacy and environmental efficacy are needed to determine a correlation between the two.

These results, along with those of Falco and Summers, 2019, indicate the importance of intervention for STEM self-efficacy. Both small-groups and inquiry-based approaches to learning STEM can have impacts on the self-efficacy that students feel within a STEM context. Beyond self-efficacy in STEM, these studies also considered the way that the students explored STEM subject areas. The following section directly focuses on this area of STEM education and the development of students' STEM identities through the exploration of STEM (Marcia, 1966).

2.2 Exploration of STEM in search of a STEM identity

Recruitment and retention of women in STEM are both problems that need to be addressed if society is going to increase the number of women in STEM professions long term (Ceci & Williams, 2010). Currently, recruitment has been a greater focus on much of the research that has been conducted. In determining best practices for recruitment, it has been found that exposing girls to STEM concepts early has a positive effect on young girls' pursuing STEM in their futures (Terlecki & Newcombe, 2005; Maltese & Tai, 2010) and the development of a STEM identity (Riedinger & Taylor, 2016). An important individual that can introduce STEM to girls at a young age, is the classroom teacher. This section of the literature review addresses the impact of the teacher's approach to teaching (Teacher Pedagogy) and The role of Technology in STEM Exploration. Central to this section are the various interdisciplinary pedagogies that teachers have adopted, as well as specific technologies that have been implemented in the classroom, in attempts to engage girls in STEM disciplines.

2.2.1 The role of the Instructor in STEM exploration

On average, in Ontario, a student receives 925 hours of instructional time per year in elementary schools (Education Improvement Commission, 1997). The importance of the approach an educator takes to teaching STEM is critical for the success of young girls in STEM (Master & Meltzoff, 2016; Ruiz-Alfonso & Léon, 2017). The early development of a STEM identity is developed through experiences and interactions with others (Speldewinde & Campbell, 2021). As such, learning environments (including the ‘where’, the ‘who’ and the ‘what’) can be structured to inform STEM identities (Bell et al., 2017; Çakır et al., 2017; Ruiz-Alfonso & Léon, 2017; Thomas et al., 2017), both positively and negatively (Corrigan & Aikens, 2020).

Educational settings provide girls with opportunities to explore – one of the key features of reaching identity achievement (Marcia, 1966). Through exploration, girls are given the opportunity to revise and refine their goals, beliefs and values (see Identity Status Theory; Marcia, 1966). At the intersection of exploration and formal education, lies the teacher. Teachers have the ability to impact STEM identity from a young age (Chapman & Vivian, 2016; Kollmayer et al., 2018; Reinking & Martin, 2018), through their approaches to teaching. The literature that exists that focuses on the impact of teachers on STEM identities for girls cites a number of factors. The most abundantly mentioned factors include the need for professional development, in order to equip teachers to promote STEM identity formation for girls, the impact of inquiry-based pedagogies, and the implementation of the Maker Movement within the classroom.

2.2.1.1 Teacher Professional Development to Promote STEM identities in girls

Unconscious bias of STEM stereotypes, that is demonstrated by teachers, impacts student’s perceptions of STEM professions (Chapman & Vivian, 2016). Although efforts have been (and are actively being) made, gender discrimination still exists in education (Kollmayer et al., 2018). Each teacher adapts their own approach to teaching, and as such, some teachers reinforce, while others challenge, the stereotypes and social norms surrounding STEM that were previously discussed (see Stereotypes in STEM disciplines) (Reinking & Martin, 2018). Although teachers do not always intentionally reinforce STEM stereotypes, these experiences have a negative impact on girls’ STEM identity development (Campbell et al., 2020; Oppermann et al., 2019; Reinking & Martin, 2018; Speldewinde & Campbell, 2021). In order to provide teachers with the skills and knowledge necessary to adequately adapt to pedagogies that challenge STEM stereotypes and to foster the development of positive STEM identities for girls, teacher professional development is necessary.

In their 2020 report, Campbell et al. compiled research related to mentoring and role models for girls in STEM. In the report, authors outline that "professional learning for educators and teachers is and remains a priority, and needs to focus on two areas, that is, a) competence and confidence to teach STEM, and b) awareness of gender issues and the way gender features in the development of STEM identities" (p. 5). These recommendations are echoed by Oppermann et al. (2019), who determined that teacher self-efficacy in science is an important mediator for girls' (aged 4-5) motivational beliefs about science.

Reinking and Martin (2018) found that educators can make specific pedagogical shifts to ensure that they are providing girls with STEM education that is engaging and promotes a passion for STEM. These approaches include: providing hands-on experiences, presenting examples of women role models in STEM, promoting creativity and positivity around STEM and allowing for collaboration and peer-to-peer learning (Reinking & Martin, 2018). Girls benefit from an early passion for STEM because they are able to develop a sense of identity within STEM, at an earlier age (Buschor et al., 2014). This early sense of identity is a predictor for their decision to pursue STEM careers (Buschor et al., 2014; Ruiz-Alfonso & Léon, 2017).

To foster an early development of passion for STEM as well as facilitate the development critical thinking (Ratto, 2011), perseverance (Hughes, 2017) and technological fluency (Kafai, 2006) teachers can adopt inquiry-based pedagogies, which utilize student interest as a vehicle for learning (Wilczek et al., 2022; Dobber et al., 2017). Inquiry-based pedagogies are founded in constructionism learning, where learning takes place "through a range of activities that blend design and technology … fabricating with new technologies to create almost anything" (Wohlwend et al., 2017, p. 445) (see Constructionism Theory).

2.2.1.2 Inquiry-Based Pedagogies

Inquiry-based pedagogies (IBP) utilize collaborative approaches to solving a problem (Wilczek et al., 2022). More specifically, it involves "pupils address[ing] questions about the natural, cultural or material world, collect[ing] data to answer these questions, analy[zing] these data and report[ing] a conclusion based on their research" (Dobber et al., 2017, p. 196). Although IBPs are often regarded as effective and engaging approaches to teaching, a critical aspect of IBPs is the need for "guided co-construction" (Dobber et al., 2017, p. 195). When teachers implement IBPs, they play a crucial role in leading, guiding and helping students co-construct their knowledge (Dobber et al., 2017).

IBP has become an umbrella term, which encompasses the different approaches to IBP that have evolved in the realm of education. These approaches including passion-based learning (Dobber et al., 2017; Hughes et al., 2020; Maiers & Sanvold, 2018; Marsh et al., 2019; Spencer & Juliani, 2017), problem-based learning (Connor et al., 2015; Hughes & Burke, 2014; Warren, 2019), inquiry-based learning (Calder, 2015; Dobber et al., 2017; Wilczek et al., 2022), and Maker Pedagogies (Geçu-Parmakisz et al, 2021;

Hughes et al., 2018; Hughes et al., 2022). Literature within this area of education has been plentiful within the last decade and many of the researchers unanimously agree that IBPs, when implemented effectively, they facilitate the development of key indicators of positive STEM identity development (Wilczek et al., 2022)

Wilczek et al. (2022) explore the impact of a shift from teaching students chemistry through the exploration of traditional experiments with predictable outcomes, to an inquiry-based approach to learn the same concepts. Their study took place at Brown University, in Rhode Island, and involved the input from 311 students who were enrolled in an introductory chemistry course (Organic Chemistry II). At the start and end of the semester, pre- and post-study surveys were administered to participants. The surveys were administered with the goal of “understand[ing] the impact of the new course design on students’ self-efficacy and science identity” (p. 1940).

Analysis of data involved the implementation of Stata SE 16.1 (an integrated statistical software), and from this, researchers calculated a measure of self-efficacy, called the self-efficacy index (SEI) and a measure of science identity, called the science identity index. Once these indexes were determined, the percent change for each individual, from the start of the semester to the end of the semester, was calculated and results were interpreted to determine the impact of the intervention.

Findings of this research indicate that when inquiry-based curriculum was implemented over the semester, students' self-efficacy and science identity increased in all demographic groups that were accounted for. More interestingly though, is that these improvements were seen most significantly in groups who identified as under-represented in STEM. Improved self-efficacy and science identity have longer term impacts, as they have been found to be predictors in the eventual pursuit of STEM careers (Stets et al. 2017; Buschor et al., 2014).

Inquiry-based pedagogies have also shown to have positive impacts on the ability for one to recognize themselves within STEM disciplines (i.e. a scientist) (Starr et al., 2020). The ability for one to recognize themselves as a participant within STEM is critical for the development of their STEM identity, and that is often coupled with competency and performance (Starr et al., 2020). The individual often follows a positive progression: authentic engagement in STEM improves self-efficacy and by improving self-efficacy, the individual's STEM identity is improved.

In their short-term longitudinal study, Starr et al. (2020) explored undergraduate students' experiences with authentic science practices in the classroom. Authentic science practices were defined as those that implement an inquiry-based approach to learning, by following the process of "constructing scientific explanations, generating hypotheses, and designing experiments" (p. 1096). Their study consisted of 1079 undergraduate students from an introductory biology course and data were collected over a 10-week term. While controlling for class size and GPA, researchers implemented structural equation modelling to test the following predictions:

- Reported experiences in performing science practices would be positively related to feeling recognized as a scientist and to perceiving the classroom climate as positive for motivation and belonging
- Recognition as a scientist would predict positive perceptions of classroom climate

- Classroom climate would predict increases over time in students' STEM motivation (expectancy-value beliefs) and STEM identity
- Increases in STEM identity would be associated with increases over time in STEM career aspirations
- Increases in STEM motivation would to predict increases in STEM career aspirations and course grade
- The model would be more strongly related to the outcome measures for students from underrepresented minority (URM) backgrounds than non-URM students

To test these predictions, participants completed pre- and post- project surveys. Questions in the surveys incorporated the following concepts: demographics variables and grades, performing science practices, recognition as a scientist, classroom climate, STEM identity, STEM motivation, STEM career aspirations, and non-STEM motivation and career aspirations.

Researchers found that there was a significant correlation between authentic science practices and positive factors that inform STEM persistence. Specifically, the implementation of inquiry-based learning through authentic science practices predicted an increase in STEM motivation and identity. This increase was mediated by others -- teachers, teacher assistants, classmates -- recognizing participants as scientists. Similar to the findings of Wilczek et al. (2022), these experiences were more impactful on URM students "that have historically been marginalized in STEM" (Starr et al., 2020, p. 1112).

Although these findings are important within the general realm of STEM, researchers also accounted for gender when considering the various mediators, and they found that there was no significant difference between males and females. Starr et al. (2020)

attribute these findings to the fact that "[their] sample comprised students in gateway biology courses" (p. 1113), and the biological sciences are among STEM fields in which women are not underrepresented (Cheryan et al., 2017). It would be interesting to compare this study to one that considers the same metrics and implements the methodology, but in a man-dominated science discipline, such as physics.

The practical implications of the research presented in this section, include supporting pedagogies that provide opportunities for students to participate in authentic inquiry processes. Through the practice of inquiry, students are given the opportunity to develop skills such as collaboration, communication and problem solving, among others.

2.2.2 The role of Technology in STEM Exploration

Technology integration in education, similar to teacher pedagogies, differs from teacher to teacher (Constantine et al., 2017). The type of technology and the way the technology is implemented within the classroom is varied and often, dependent on the teacher's comfort level in using technology (Constantine et al., 2017). However, as mentioned previously, technology has become central to STEM disciplines, and as such, is central to this thesis.

The specific technologies that are considered in this thesis include coding and the Internet of Things. The current research on these subject areas is presented and reflected upon through the lens of STEM identity development for girls.

2.2.2.1 Coding

In search of an effective conduit to deliver STEM curriculum and to engage students in process that enable the development of task-oriented skills, such as coding, education has taken a shift to include coding into curriculum. In 2020, a new mathematics curriculum was introduced in Ontario and coding skills were included, explicitly, with the intention of students improving problem solving skills and developing technology fluency (Ontario Ministry of Education, 2021). With this shift, this thesis focuses on coding as one of the main methods for delivering STEM content to research participants. The current body of literature helps inform this implementation of coding in the context of this thesis.

In 2017, Çakır et al. published research that focused on identity development in coding, for girls. Their research was guided by the hypothesis that "by presenting software programming in a way that facilitates identity exploration early on, young girls will be more likely to consider careers in CS later in life" (Çakır et al., 2017, p. 115). A mixed-methods approach was used in their study and the participants consisted of 21 girls, aged 5-8.

Research was conducted over a one-day workshop, which focused namely on coding and game design for girls. Participants were introduced to the Unity game development engine, as well as the game that they would be improving throughout the morning. During the second half of the day, the participants were challenged to use their knowledge and skills to create an extension of the initial game.

Findings from Çakır et al.'s research indicate that the workshop did contribute to a positive shift in attitudes towards pursuing careers within computing. The participants demonstrated evidence of an improved confidence in gaming and game design, through comments such as " … based on the stuff I did today, it was easier than I thought. Before the workshop, I didn't know about the designing part, just the coding part, so it was very basically just stay away from it - I don't understand it at all. It's still confusing but I understand it better" (Çakır et al., 2017, p. 124). This improved confidence in coding may have contributed to the shift in attitudes; which demonstrates the importance of exploration within STEM contexts, in order to inform identity formation. The findings in this research also demonstrate that the participants were able to effectively and creatively engage with the task that was given to them. That, consolidated with the confidence gain, confirms the importance of interventions to improve self-efficacy, as discussed in Inquiry-Based Pedagogies.

The importance of confidence in STEM, as a result of exploration within coding, is echoed in the work done by Hughes et al. (2021). Through the utilization of the science identity framework, their researched aimed to examine girls' coding identity development, with an end goal of developing a coding identity framework. Within this study, Hughes et al. (2021) proposed that "girls need to have opportunities to demonstrate their competence and be recognized as coders" (p. 427). This research used a mixed methodology, employing a number of data sources, including: participant applications, pre- and post-survey instruments, video observations, and focus groups. From these data sets, researchers chose three participants to conduct case study analysis on. Data sets were analyzed and thematic coding was used to create narratives for each of the three cases.

The findings of Hughes et al.'s research shed light on the importance of giving girls exploratory experiences, in attempts to improve their coding identities, and in turn, their STEM identities. The results indicate that all three cases in this study left the camp with improved coding identities. Beyond that, this study also highlights that "there are diverse identities within coding that can allow various personalities to see themselves as coders” (Hughes et al., 2021, p. 450). These findings are critical in understanding how girls can develop coding identities, which can inform their decisions to pursue STEM professions. Findings of this research also indicate the role that educators have in fostering the different identities that girls develop as they interact with coding more. In addition to addressing the importance of educators addressing innate biases that they possess, authors indicate that

> educators can try out and perform new instructional practices as they work to help girls develop coding identities in ways that meld with their existing salient identities and champion those identities among the peers that they collaborate with. (Hughes et al., 2021, p. 451)

These findings align with those that are explored in The role of the Instructor in STEM exploration, which focus on the impact that educators have on the development of STEM identities for girls.

The current literature that focuses on coding and the development of STEM identities indicates the importance of providing girls with opportunities to learn, gain confidence and grow within coding. In doing this, girls have opportunities to explore and develop aspects of their STEM identities – a critical component of choosing a profession.

2.2.2.2 Internet of Things

In addition to the impact that coding experience has on girls’ STEM identities, a new vehicle that could be used to promote the development of a STEM identity is the Internet of Things (IoT). The importance of introducing IoT to young students is considered in this literature review, as engagement and participation with the technology might play a role in the way that IoT is utilized in society. The research that is focused on IoT in education is limited, and often focuses on the use of IoT for administrative purposes (attendance, sharing data) (Kassab et al., 2020) and the creation of ‘smart schools’ using pre-programmed technologies, as opposed to focusing on the use of IoT to engage students in the creation of technology solutions (Kiryakova et al., 2017).

Daily, IoT plays a critical role in smart homes, traffic logistics, environmental protection and personal health (Li, H. et al., 2017) and at the time of writing, it was projected that there would be 20.4 billion devices connected to IoT (Kassab et al., 2020). In education, IoT is still far from being seamlessly integrated (Schaffhauser, 2018). Currently, IoT in education is most often used in projects that focus on lighting, climate control and transportation (Schaffhauser, 2018), and in the creation of Smart School, Smart Cities and Smart Homes (Kiryakova et al., 2017). The use of IoT as a vehicle for discovery and creation of knowledge is relatively unknown. It may affect the teaching and learning processes, but because of its emergent nature, there is still very little known about it.

Kassab et al. (2020), conducted a literature review that focused on the benefits and challenges of IoT use in education. Only 1.85% of the studies used in their review were from Canada, which emphasizes the need for research in this area for Canadians. Of the studies considered, a common theme was the use of IoT by educators for administrative purposes (such as managing attendance, tracking students). From the students’ perspective, IoT was used often to assist in things like sharing data and creating differentiated learning opportunities. These findings are interesting, considering that Chin and Callaghan (2013) found that as a subject, IoT is a highly exciting and stimulating topic to attract students and an ideal platform for teaching computer science concepts. Much of the current research that has been conducted with IoT at the centre has not taken into consideration the use of IoT as a learning vector, beyond that of a ‘tool’ to help manage information.

One exception to this is the research of Willner-Giwerc et al. (2020), who utilized a system they created, coined *The SymbIOTics system.* They recognized that although the IoT technology that is available for classrooms is good, “teachers are left with an inability to enable students to actually create their own smart, connected solutions to engineering design problems” (Willner-Giwerc, 2020, p. 65). Through the SymbIOTics system, this research aimed to create an interface that allowed elementary aged students to create with IoT, instead of just ‘consume’ it. Their findings indicate that students successfully utilized IoT to create solutions for various engineering problems, however, there were still barriers to utilizing IoT in the classroom. The major concern with IoT was reliable access to an internet connection.

Similar to the findings of Willner-Giwerc et al. (2020) are the findings of Kortuem et al. (2013). This United Kingdom based study was conducted at the Open University, the “world’s first successful distance teaching university” (Kortuem et al., 2013, p. 54). At Open University, IoT was introduced to students through the implementation of a course entitled My Digital Life, which had goals related to understanding computing concepts like algorithms, programming and sensor implementation, to students who have never learned these concepts before. The curriculum that was developed for this course had an emphasis on collaborative learning and shifting from technology consumers, to technology innovators (Kortuem et al., 2013).

The findings of this research were informed by the comments and questions asked by students on the course's online support forum, as well as the comparison of marks between this cohort of students, and an earlier cohort that took a course with an "older traditional introductory computer science module" (Kortuem et al., 2013, p. 59). It was determined that the delivery of this computing course through the learning and implementation of IoT was successful, however, the success and dropout rates were on par with that of the previous computer science course offered at the school. Although the extent of which the students could successfully develop networked applications was less than Kortuem et al. (2013) expected, they did note the impact that IoT learning had on intrinsically motivated learning. It was noted that

> [a]lthough [they] provide[d] introductory activities, many students design[ed], create[d], and share[d] their own projects. A significant number of students jump[ed] ahead in the course material and start[ed] working on their own projects even before any formal [IoT] teaching has taken place (p. 57).

The importance of passion and student-centered learning, that is supported by critical pedagogies and constructionist approached to learning, is clearly demonstrated by Kortuem et al.'s (2013) research. It is critical that students gain knowledge and skills that can be applied to IoT, so that "[l]earning to code and operate connected systems [are not] an end in itself, but a path for our students to implement ideas, and enhance their impact in a technological world" (Lorenzo & Lovtskaya, 2021, p. 11).

2.3 Limitations in Current Research

As we move into the third decade of the 21st century, it is more important than ever that the discrepancy in numbers between men and women in STEM professions is addressed. With a more diverse workforce, comes differing perspectives and opinions that can be used to initiate important conversations about the needs and wants of a wider array of people. As of 2016, in North America and Europe, only 31% of women specialized in science, engineering, mathematics or computing (Schmuck, 2016). As a result of the observed imbalance in numbers of men versus women in STEM careers, a body of research has emerged to try and address this issue.

Currently, there is a large body of research on identity and factors that inform one's identity, but the research that focuses on the development of a STEM identities for girls is limited. Much of the research on women in STEM focuses on the retention of women in STEM fields (Castro & Collins, 2021; Lin & Deemer, 2021; Xu, 2017). That said, there is a small body of research that focuses on the pursuance of STEM professions, but much of it looks at individuals who are pursuing post-secondary degrees, so they are later in their lives. This leaves room for research that centers around school aged girls (6-18 years old) and how their lived experiences may impact their career trajectory. This research is not a longitudinal study, so in the greater scheme of things, it cannot be determined whether the participants end up pursuing STEM or whether this week-long camp had a lasting impact on the participants' decisions to pursue STEM careers. However, the aim of this research is to gain insight into the short-term, just-in-time impacts that different variables have on girls learning STEM and their perceptions of their STEM identities.

An important factor that has been considered in this literature review is passion as a driving force for the pursuance of STEM careers, and the impact that passion has on motivation to learn STEM concepts. There is a large body of work that indicates the importance of passion when individuals make career decisions (Chichekian & Vallerand, 2022; Ruiz-Alfonso & León, 2017; Zhang & Zhang, 2022). Passion has been explicitly proven to influence one's career pursuance. However, gaps in current literature include the intersection of passion and motivation as driving factors for exploration and in turn, the impact that it has on STEM identity formation. As such, this research aims to make connections between these variables, to better understand how an individual can allow their passion to motivate them to learn STEM at a younger age. The aim is to gain a clearer understanding of how young girls can explore STEM as a result of intrinsic motivation (a desire to explore it) and the impact (if any) that this exploration has on the nourishment of their STEM identity.

Other factors that contribute to STEM engagement, that have been considered in this literature review include: the impact of the pedagogical approaches that teachers use to teach STEM and various technologies used to teach STEM (including coding software and IoT). The Internet of Things refers to the interconnection of technologies, which has been utilized largely in education for administrative purposes (Kiryakova et al., 2017; Schaffhauser, 2018). At the time of writing, there was limited research on IoT and the efficacy of it as a learning tool for young individuals to explore STEM. The potential of IoT as an inquiry vector that allows for passion learning is unknown, largely because of the steep learning curve that is associated with learning how to create with it (Willner-Giwerc et al., 2020). IoT in education can create opportunities for customization, enhance motivation for learning and capture interest from students. This research utilizes IoT for exploration of personalized approaches to solving civil issues, in attempts to elicit authentic passion-based learning, driven by each participant's perspective on what constitutes a civil issue. With this in mind, this thesis aims to fill the gap in literature that exists at the intersection of pedagogical approaches, the use of IoT as a vehicle to teach STEM and the impact that those factors have on exploration.

Ultimately, the research at the heart of this thesis, aims to fill the void found in the literature around girls' STEM identity development and factors that can moderate the development. Although the body of literature that focuses on girls in STEM is becoming more comprehensive as society moves forward into a future of innovation, the concerns surrounding *how* girls can develop STEM identities drives this research. The ultimate goal of this research is to contribute to the larger body of literature, in efforts to support the wider goal of increasing the pipeline of women going into STEM professions.

Chapter 3. Theoretical Framework

The issue of women in STEM is a multi-faceted one, as demonstrated in the literature review. This theoretical framework is compiled in an effort to gain knowledge and paint a clearer picture of the factors that impact women in STEM, through the lens of established theories. These foundational theories ground the research in order to meaningfully compare patterns of behaviour among various contexts. The theories that have helped drive the research presented in this thesis include Identity Status Theory (Marcia, 1980), Critical Theory (Freire, 2005; Govender, 2020), Constructionism (Papert, 1980), Self-Determination Theory (Deci & Ryan, 1985) and Self Efficacy Theory (Bandura, 1978).

3.1 Identity Status Theory

In 1966, James Marcia proposed the Identity Status Theory. Marcia believes that identity is a self-structure that he explains as "an internal, self-constructed, dynamic organization of drives, abilities, beliefs, and individual history" (1980, p. 159). He proposed that identity is fluid and not static; people can change and are not confined to an identity indefinitely (Marcia, 1980). The Identity Status Theory aims to understand identity within these constraints.

This theory states that identity construction is based upon independent aspects of exploration and commitment. Cote and Schwartz outline that "exploration represents the search for a revised and refined sense of self, whereas commitment represents the choice to pursue a specific set of goals, values, and beliefs" (2002, p. 610). Both exploration and commitment are critical when determining one's identity.

Marcia's research that established the identity status model was founded in Erikson's research on identity formation (1968). Erickson's Stages of Psychosocial Development explores the stages for psychosocial development from infancy to adulthood. In some of his most well-known research, Erikson focuses on the identity formation through two behavioural indicators: exploration and commitment (Mancini, 2015). Exploration refers to active questioning and consideration of alternate identity components, including values, beliefs and goals (Mancini, 2015). Commitment consists of choosing a relatively firm identity, which results in firm choices and engaging in activities that are aligned with that identity (Mancini, 2015).

Building on this, Marcia (1966) developed a study that aimed to expand on these two domains of identity development. Marcia's (1966) research study consisted of semi-structured interviews and incomplete sentence tests. This research was conducted with 20 participants and aimed to determine the overall ego identity and identity status of participants. This research utilized Ego Identity Incomplete Sentence Bank (EI-ISB), which required participants to complete 23 sentences, which were developed to echo the achievement of Ego Identity, as outlined by Erikson (1956). In addition, Concept Attainment Task (CAT), a concept developed by Bruner et al. (1956) was used, where participants were given specific points for determining attributes that were present on cards given to them (Marcia, 1966). A Self Esteem Questionnaire (SEQ-F), was also given to participants at various points in the study. The SEQ-F was developed by deCharms and Rosenbaum (1960), and consisted of 20 item questions that gauge an individual's feelings of self-worth and worthiness (Marcia, 1966).

Following the experimental procedure, which saw the administration of the above tests, in addition to the semi-structured interviews, Marcia was able to determine profiles for four identity statuses, which are outlined in Table 3.1.

Table 3.1
Marcia's Identity Profiles

Profile	Findings
Identity Achievement	Presence of exploration and commitment
Moratorium	Presence of exploration but lacking commitment
Foreclosure	Presence of commitment but lacking exploration
Identity Diffusion	Absence of both commitment and exploration

This study contributes to the knowledge about the transition from adolescence into adulthood, and with it, the formation (or lack thereof) of identity. Marcia's research has become central to research on identity formation in various domains, education included.

From these findings, Marcia is able to determine the importance of each profile as it relates to coping with "psychosocial tasks of forming an ego identity" (Marcia, 1966, p. 558). Each of these identity profiles aligns with somewhat predictable personality characteristics of individuals who fall under each profile. Identity diffusion is indicative of an individual who has yet to begin exploration of identity and with that, have not committed to an identity. Individuals who resemble the moratorium profile have begun to actively explore identity, but they still lack a commitment to an identity. They are still in search of an identity that aligns with their beliefs, values and goals. Foreclosure, on the other hand demonstrates individuals who have committed to an identity with a lack of exploration. The beliefs, values and goals that these individuals hold onto are often influenced or expected by others. Finally, identity achievement is indicative of the presence of exploration and commitment. These individuals have had ample exploration that has informed their beliefs, values and goals, which has ultimately, allowed for them to commit to an identity.

3.2 Critical Theory

This thesis research aims to learn about perceived abilities of girls in STEM disciplines. In the grand scheme of this area of research, the importance of perceived abilities lies in the likelihood of a girl to pursue a career in a STEM discipline. As previously mentioned, there is a disproportionate number of men to women who retain careers in STEM disciplines. Critical Theory intersects with this research, as the research attempts to shed light on recruitment of girls into STEM careers, thus challenging the uneven representation in these careers. This notion of challenging societal norms has been acknowledged in literature for hundreds of years. In the late 1700s, a German named Immanuel Kant proposed the critical philosophy, in his work *Critique of Pure Reason* and along with Karl Marx's 1848 *Communist Manifesto*, which challenged capitalism, the Frankfurt School originated (Mckernan, 2013). Years later, the contemporary Critical Theory was born. In the early 20th century, Critical Theory emerged as a way to "identify the conditions and possibilities for liberation from oppressive social systems without associating itself with any given political system" (Govender, 2020, p. 206). Race, class, gender, religion and cultural dynamics are all acknowledged as variables that contribute to social systems, and therefore, factors that impact oppressive circumstances (Wang et al., 2019). The aim of Critical Theory is to challenge these aspects of society that are taken for granted, in order to seek social justice for those who are oppressed (Wang et al., 2019; Bachmann, & Moisio, 2020). As outlined by Bachmann and Moisio,

> Critical theory is fundamentally concerned with human beings [Menschen] and their possibilities for fulfilment or, rather, self-fulfilment and asks the question of why Menschen are prevented from such fulfilment or, in the words of our translation, why they are prevented from emancipation from enslaving conditions. (2020, p. 255)

Aligned with Critical Theory is Paulo Friere's Critical Pedagogy, which is a "movement involving relationships of teaching and learning so that students gain a critical self-consciousness and social awareness and take appropriate action against oppressive forces" (Mckernan, 2013, p.425).

Freire's concept of Critical Pedagogy emerged as a "response, of a creative mind and sensitive conscience, to the extraordinary misery and suffering of the oppressed around him" (Shaull, 2005, p. 30). In his work *Pedagogy of the Oppressed*, Freire (2005) identifies that in order for the oppressed to reach freedom, the pursuit the conquest must be persistent and done responsibly. He goes on to state that "[t]o surmount the situation of oppression, people must first critically recognize its causes, so that through transforming action they can create a new situation, one which makes possible the pursuit of a fuller humanity" (Freire, 2005, p. 47). It is important to note that the circumstances and causes of oppression vary, depending on the oppressors and the impetus of the oppression. The oppressed become compliant and accept their oppression, in fear of greater repression (Freire, 2005). As a result, the oppressed "are inhibited from waging the struggle for freedom so long as they feel incapable of running the risks it requires"

(Freire, 2005, p. 47). The exception to this is the oppressed who have the fearlessness to challenge their oppressors, so long as they have comrades who are willing to face the fight alongside them (Freire, 2005). The significance of Freire's research, lies in the fact that the oppressed need knowledgeable allies in order to combat their oppressive circumstances.

Critical Theory and Critical Pedagogy can be considered through a number of lenses, because of the various factors that contribute to the oppressive conditions that this theory recognizes. One lens that can be applied is that of Liberal Feminism, which posits that women and men are fundamentally equal, but social conditions establish disparity between the sexes (Sharma, 2019). Liberal feminists believe that women do not have the opportunity to live a life of autonomy because of the restrictions and limitations that are placed on women by society (Baehr, 2021). Autonomy of career choice relates directly to a woman's opportunity to pursue a career where she feels fulfilled and valued. The positioning of Critical Theory and Liberal Feminism acknowledges that there are societal norms that exist and act as barriers for women to pursue, and hold, positions in careers that are male dominant. Education plays an important role in either addressing or conforming to these norms and must therefore be considered within the realm of society.

Critical Theory in education has been molded into various pedagogical approaches, which utilize the application of knowledge through a critical lens. Foley et al. outlines that

> Critical Pedagogy stresses the task for teachers to develop very specific classroom processes designed to promote values and beliefs which encourage democratic, critical modes of teacher-student participation

> and interaction stripped of egoistic individualism. These values and processes include developing in students a respect for moral commitment and social responsibility. (Foley et al., 2015, p. 117)

Traditionally, educators have taken the position in the classroom as the knowledge holders, who unidirectionally, pass down information to students. In this sense, students are not active in their learning process, instead, they simply receive the information. When critical theory is leveraged,

> the teacher cannot think for her students, nor can she impose her thought on them. Authentic thinking, thinking that is concerned about reality, does not take place in ivory tower isolation, but only in communication. If it is true that thought has meaning only when generated by action upon the world, the subordination of students to teachers becomes impossible. (Freire, 2005, p. 77)

Critical pedagogies create the opportunity for students to become active in their learning, which creates a bi-lateral movement of knowledge between the learners and the teacher, or as Freire (2005) puts it "teacher-student with students-teachers" (p. 80).

Through the use of Critical pedagogies, the learner must become more 'conscious' of their situation and of how to change it: a process Freire termed 'conscientisation' … throughout Freire's work, there is a discernible and sometimes forcefully expressed concern with 'authenticity'. For Freire, authentic learning is critical, rational and transformative … Only modes of learning that lead to emancipation then can truly be regarded as authentic (Serrano et al., 2018, p. 10).

The importance of authenticity is crucial for this approach to learning. This research is positioned within critical pedagogy because of the authenticity that it elicits. The importance of the identity of the researcher relates back to the feminist theory, in that "the pedagogy of the oppressed cannot be developed or practiced by the oppressors," (Freire, 2005, p. 54). For research such as this to be authentic, those conducting the research must be on the side of the oppressed -- which is the case for this thesis.

I am a woman and my lived experiences dissuaded me from pursuing a career in a discipline that is traditionally seen as male-driven. These aspects of who I am and how I perceive the imbalance in STEM professionals create a foundation for authentic research in this area. I am in a position where I can use resources and opportunities that I have been afforded, to contribute to the literature that is available on girls in STEM. As more research is conducted and literature is published, it might be possible to elicit change in our society, through political reform and a shift in the climate of STEM professions.

3.3 Constructionism

One of the research questions that guides this research is "Do the personalized possibilities of the Internet of Things increase motivation to participate in STEM learning at a week-long March Break Camp?" To answer this question, the research design is grounded in the implementation of a passion project, which is done to set the stage for participants to construct their own understanding of IoT. Constructionism is a theory that positions the learner at the centre of learning, and posits that knowledge is actively acquired through experiences where "the learner is involved in the active construction of objects meaningful to [them]" (Lodi & Martini, 2021, p. 892). Constructionism builds off of Piaget's Constructivism theory, but differs in that

> [c]onstructionism—the N word as opposed to the V word— shares contructivism's view of learning as "building knowledge structures" through progressive internalization of actions … It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe. (Papert & Harel, 1991, p.1)

The importance of an inquiry-based approach to learning is stressed in both of these theories, as well as a number of other educational theories. Inquiry-based learning is a learner centered instructional method based on the learner's discovery of knowledge through active participation and learner responsibility (Suárez et al., 2018).

This research is grounded in Constructionism as it positions the research participants as the 'builders' of their knowledge through inquiry (Papert, 1980). One key component of Constructionism is that the learner constructs a tangible demonstration of their learning (or artifact), whether that be physical or digital (Lodi & Martini, 2021). The other aspect of Constructionism is the fact that the 'builder' has control over the materials that they choose to build with. The choice that is made differentiates from individual to individual, which highlights the importance of the "fundamental affective component" (Lodi & Martini, 2021, p. 892). As individuals quench their curiosities through this inquiry-based approach, they have the opportunity to express their learning through a means that they deem effective and that creates an opportunity for individuality in learning. This individualised approach to learning leads to passion-based learning and the importance of learning through one's interests.

Papert's constructionism theory has been foundational in the establishment of the Makerspace Movement, which also employs the inquiry mindset. Makerspaces are derived from the maker movement, which was founded in the Do-It-Yourself (DIY) movement (Bullock & Sator, 2018). These movements have promoted the shift from a consumer society, to a creator society (Bullock & Sator, 2018). Makerspace learning embraces a more flexible approach to learning, where the learner pursues knowledge through the tools and processes that they choose (Hughes et al., 2020). As Wohlwend et al., (2017) explain, making includes "a range of activities that blend design and technology, including textile crafts, robotics, electronics, digital fabrication, mechanical repair or creation, tinkering with everyday appliances, digital storytelling, arts and crafts--in short, fabricating with new technologies to create almost anything" (p. 455). This research was conducted within a Makerspace setting and as such, constructionist approaches to learning were implemented, as participants engaged with their learning of new technologies.

These philosophies for teaching and learning have been linked to critical thinking, innovation and creativity, self-directed learning, collaboration, communication and citizenship (Häkkinen et al., 2017; Reinking & Martin, 2018). Thus, critical making occurs when making meets critical theory (Ratto, 2011). These skills are among those that are considered essential for success in the 21st-century workplace (Jang, 2016) -- a workplace that is vastly different from that seen in the 20th century.

3.4 Self-Determination Theory

Self-Determination Theory (SDT) is a framework that helps qualify motivational factors that "facilitate or undermine intrinsic motivation, autonomous extrinsic motivation, and psychological wellness" (Ryan & Deci, 2020, p. 1). As outlined above, constructionist learning is implemented in this thesis, and as such, understanding the motivation that helps to drive the learning and inform the passion is crucial. It is important to understand the theoretical components of motivation in the classroom, in order to understand how that might play a role in how girls engage with learning STEM, and in turn, their perceived abilities in STEM. SDT aims to determine which motivational factors have an impact on learning and achievement in the classroom.

Motivation can be classified into either intrinsic or extrinsic (or amotivation, in which individuals are unmotivated; individuals passively engage without any sense of intention) (Ryan & Deci, 2020; Standage et al., 2006). Intrinsic motivation related to activities that people participate in for their own enjoyment or interest (Ryan & Deci, 2020). In relation to constructionist learning, "[p]lay, exploration and curiosity spawned activities exemplify intrinsically motivated behaviours, as they are not dependent on external incentives or pressure, but rather provide their own satisfactions and joys" (Ryan & Deci, 2020, p. 2). The positioning of exploratory learning next to inquiry-based learning emphasizes the overlap of these concepts.

Incongruously to intrinsic motivation is extrinsic motivation. Extrinsic motivation is identified as motivation that is controlled (Standage et al., 2006); this motivation comes as a result of actions that originate from reasons other than personal satisfaction (Ryan & Deci, 2020). This kind of motivation is the result of external rewards that drive an individual's actions (Table 3.2). An example of this in education are the marks that students receive, as a result of their efforts to understand a concept.

Table 3.2
The Four Subtypes of Extrinsic Motivation, and their Describers (Ryan & Deci, 2000)

Extrinsic Motivation Subtype	Description
External Regulation	behaviour that is driven by compliance. This type of regulation implicates fear of punishment or actions that are done in order to gain a reward.
Introjected Regulation	behaviour is dictated by avoidance of shame, guilt, failure or anxiety. This type of regulation has strong ties to self-esteem and ego-involvement.
Identified Regulation	behaviour that comes as a result of a conscious valuing of the activity being done. This type of regulation comes as a result of personal importance of the task.
Integration Regulation	behaviour that is rooted in an identified value in the activity. This type of regulation is the most similar to intrinsic, but still differs because of the lack of interest and enjoyment that is seen.

These motivational behaviours form a framework for self-determination. In identifying the type of motivation that participants engage in, likely outcomes can be predicted. It has been noted that "a large empirically-based literature has demonstrated the positive relations of more autonomous forms of classroom motivation with academic outcomes … This is likely due in part to the greater effort students put forth when autonomously motivated" (Ryan & Deci, 2020, p. 3). The motivational regulation that informs the participant's actions is a crucial component of this thesis because of the intersection between that and constructionist learning.

In addition to identifying the type of motivation that participants engage in, there is an "assumption that the nature of the social context influences an individual's motivation, well-being and performance" (Standage et al., 2006, p. 102). Deci and Ryan (1985) determined that environments that support autonomous behaviours (such as those that are cultivated by constructionist learning), which promote choice and initiation, “facilitate self-determined motivation, healthy development, and optimal psychological functioning” (Standage et al., 2006, p. 102). However, social contexts do not directly impact these outcomes, rather, they are as a result of the fulfilment of three innate psychological needs:

> Autonomy (i.e., the need to be agentic, give input, self-endorse activities and beliefs), competence (i.e., the need to effectively interact with one’s environment and yield wanted effects and outcomes), and relatedness (i.e., the need to feel connected and close with significant others). (Standage et al., 2006, p. 102)

The three factors help to create identifiable indicators of motivation, and as such, can be used to determine where an individual might fall on the self-determination continuum.

The importance of motivation is strongly considered in this thesis because of the autonomous nature of constructionist learning. It is important to note, that in this context autonomous does not mean ‘alone’, rather it implies that the individual is an agent in -- and is given the freedom to -- guide their own learning. The design and the methodology of this research are grounded in self-determination theory, as autonomy, competence and relatedness are three of the pillars that support the individual’s perceived abilities while engaging with Internet of Things (IoT) and their passion projects.

3.5 Self-Efficacy Theory

Self-efficacy is defined as “the self-perceived ability to perform a task successfully” (Lam et al., 2014, p. 65). This final theory is critical for contextualizing the perceived abilities that the participants have. The overarching research question being asked is “How do perceived STEM abilities shift for three girls, aged 10-13, from beginning to end of the Changemakers March Break Camp?” This theory grounds the research and allows researchers to consider the way that participants interact with the activities, and how that demonstrates self-perceived abilities.

Developed in 1977 by psychologist Alex Bandura, self-efficacy theory is a subset of his earlier social cognitive theory. Social cognitive theory posits that "behaviors are learned, and two cognitive processes are involved that influence adherence behaviors: self-efficacy and outcome expectation" (Modi & Driscoll, 2020, p. 10). Self-efficacy theory, however, aims to understand the way that individuals interact with activities, based on their self-perceived abilities to be successful in those activities (Bandura, 1978). The key to this is the fact that the abilities are self-perceived; it is not focused on the skills that someone actually possesses, but how one perceives their skills and abilities (Montcalm, 1999). Self-efficacy theory also relates to "how much effort people will expend and how long they will persist in the face of obstacles or aversive experiences. Because knowledge and competencies are achieved through sustained effort, any factor that leads people to give up readily can have personally limiting consequences" (Bandura, 1978, p. 237). The effort that is put forth by individuals who feel like they can be successful in any given task, is an important consideration for individuals who are given the opportunity to interact with and explore experiences that were previously unclear or unknown to them.

This thesis has roots in self-efficacy theory, as the participant's perceived abilities while working with IoT and new technologies is central to the purpose of this research. The body of research available has determined that self-efficacy is an important factor in the success of women who pursue a career in engineering (Montcalm, 1999). As girls and women interact with activities that are akin to engineering, it is critical to understand the factors that contribute to their self-efficacy in those activities, to ensure that their motivation to persevere within that discipline is maintained. Self-efficacy is an indicator of academic achievement (Schunk & Mullen, 2012), and as such, has impacts on post-secondary, and ultimately career trajectories.

There are four informational sources that are central to Self-Efficacy theory: “performance accomplishments, vicarious experience, verbal persuasion, and physiological states” (Bandura, 1977, p. 191) – see table 3.3.

Table 3.3
Four informational sources, central to self-efficacy theory (Bandura, 1977)

Informational Source	Description
Performance accomplishments	based on “personal mastery experiences” (Bandura, 1977, p. 192); the more times that someone interacts with an activity and the interaction yields successful outcomes, the stronger their self-efficacy outcomes (Bandura, 1977). Additionally, the stronger the self-efficacy, the less negative the impact when the individual is unsuccessful (Bandura, 1977). What is more notable, is the ability for one to transfer efficacy in one scenario to efficacy in another different, but similar scenario (Bandura, 1977).
Vicarious Experience	relates to an individual witnessing the success of others and interpreting it as an opportunity for them to also be successful in said activities (Bandura, 1977). Vicarious experiences rely on social comparison, and therefore, it is not as reliable for determining self-efficacy outcomes because “the efficacy expectations induced by modelling alone are likely to be weaker and more vulnerable to change.” (Bandura, 1977, p. 197).
Verbal Persuasion	a result of the impact that suggestive comments have on individuals to “successfully [cope] with what has overwhelmed them in the past” (Bandura, 1977, p. 198). Similar to vicarious experiences, verbal persuasion is less reliable at predicting stronger self-efficacy outcomes because “they do not provide an authentic experiential base for [the outcomes]” (Bandura, 1977, p. 198).

Informational Source	Description
Physiological States	refers to the impact that stress or "emotional arousal" (Bandura, 1977, p. 198) has on an individual. Bandura (1977) explains that "high arousal usually debilitates performance, individuals are more likely to expect success when they are not beset by aversive arousal than if they are tense and viscerally agitated" (p. 198). Additionally, high emotional arousal often results in avoidance behaviour, which limits one's exposure to experience, ultimately weakening self-efficacy expectations (Bandura, 1977).

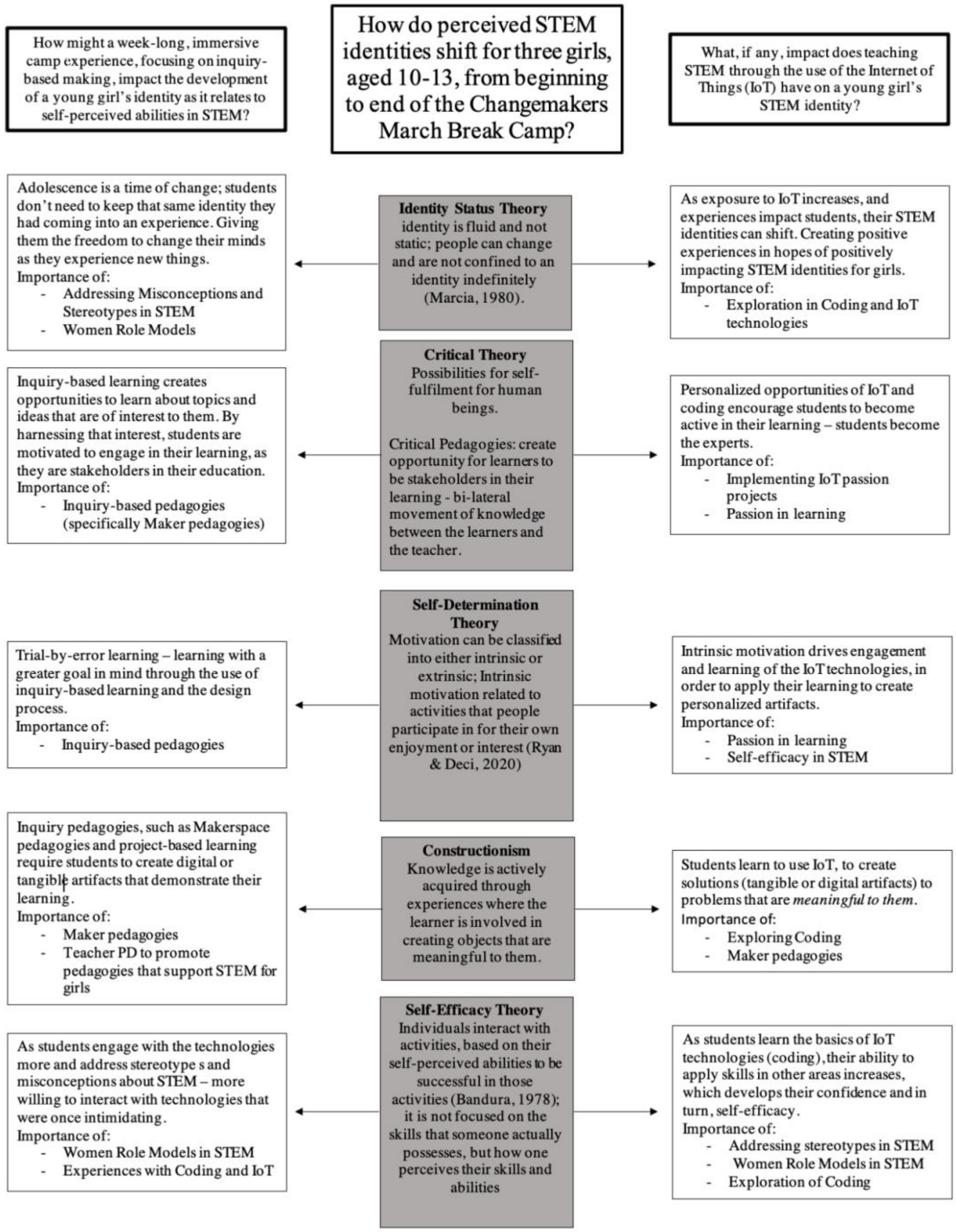
These sources all impact the efficacy expectations that one has for any given activity. Efficacy expectations can also vary, because of the complex nature of humans. They can differ in magnitude and as such, "the efficacy expectations of different individuals may be limited to the simpler tasks, extend to moderately difficult ones, or include even the most taxing performances" (Bandura, 1977, p. 194). Expectations can also differ in generality, which relates to the specificity of a mastered activity (Bandura, 1977). The mastering of some activities leads to crossover into mastery in other contexts (more general), while others do not (Bandura, 1977). Finally, expectations can also vary in strength. Weak expectations can be easily impacted by a threatening experience with the activity that is being engaged in; however, strong expectations result in the individual overcoming the threatening experiences and maintaining self-efficacy (Bandura, 1977).

3.6 Conceptual Framework

To demonstrate the connections between the research questions, literature review and conceptual framework, figure 3.1 has been created.

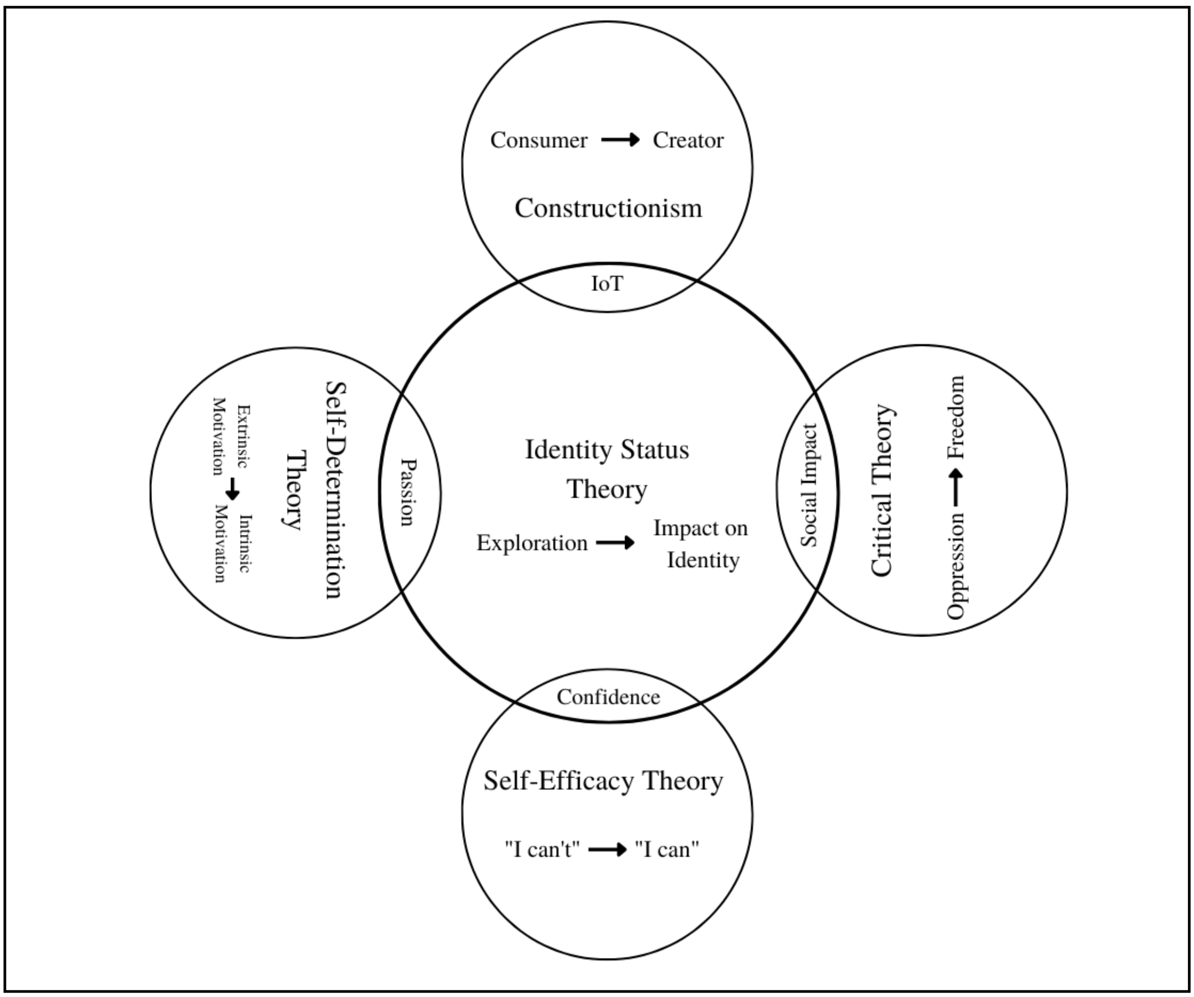
Figure 3.1

Overlap of Research Questions, Literature Review and Theoretical Framework



Each of the theories that have been addressed in this section have impacts on identity, specifically, girls' STEM identities. STEM identities are "socially based identit[ies] grounded in the extent to which individuals see themselves and are accepted as a member of a STEM discipline or field" (Kim et al., 2018, p. 591). As such, overlaps between the various theories that have been explored in this section can be identified. To visualize the intersections and influences of each theory on this thesis, a theoretical framework has been created, as shown in figure 3.2.

Figure 3.2
Theoretical Framework



Identity Status Theory is impacted by experiences; as people gain new experiences in their lives, they can make more informed decisions about identity, leading them closer to identity achievement. The expected experiences in this research that help to guide the research design include: interactions with IoT, opportunities for individuals to pursue a passion of theirs, activities that are scaffolded to promote success and therefore, confidence and demonstrations that challenge societal misconceptions about women in STEM. It is through these methodological approaches and deliberate research design decisions that this theoretical framework comes to life.

Chapter 4. Methodology

This research comprised a subsection of a Canada Research Chair (CRC) grant, which had the following objectives:

- to develop and evaluate constructionist pedagogies and the resulting competencies that arise as a result of this learning approach;
- to observe and evaluate the impact of a maker-space that facilitates the discovery, design, and development (3Ds) of digital "products";
- To build capacity for investigating and promoting innovation in formal and informal education settings in the use of emerging digital media and interactive tools.

In the context of the greater study, this research addresses all three objectives as it aims to determine the impact of the innovative ways that three girls interacted with digital 'maker' tools, in a week-long March break camp.

4.1 Overview

A qualitative case study (Stake, 2006) approach was used in this study. In education, qualitative research is a powerful tool that is used to collect in-depth, contextual data that enables researchers to examine the factors that impact humans on a daily basis. Miles and Huberman (1994) state that "[b]y looking at a range of similar and contrasting cases, we can understand a single-case finding, grounding it by specifying how and where and, if possible, why it carries on as it does" (p. 29). The importance of "where" is central to this thesis, because of the specific context where the research was conducted. A March break camp, that is focused on IoT through the lens of making positive change in the world, creates a limited viewpoint through which the phenomena can be analyzed and that is the goal here; in this idea lies the strength of utilizing the case-study methodology for this research. In his analysis of misunderstandings of case studies, Flyvbjerg (2010) outlines that often, people get caught up in trying to make generalizations about phenomena. However, because of the complexity of human nature, concrete, context-dependent knowledge is more valuable than general, theoretical (context-independent) knowledge.

This research is not meant to create generalizations about girls who learn STEM from day-to-day; rather, it is meant to get a glimpse of how girls interact with STEM in this specific context: a week-long, immersive camp experience, focused on inquiry-based making. The specific context of this research was planned, in hopes of contributing to the body of literature related to promising practices for encouraging girls' participation in STEM subjects. In an ideal world, this research would contribute to fixing the "leaky pipeline" of women in STEM, but people are complex and social constructs are not that simple. It would require more than one Master's Thesis in Education to even begin to solve this problem. Through lessons learned and insights gained in this research, the ultimate goal in writing this thesis is to contribute to the body of knowledge that is available on promising practices for teaching girls STEM.

Stake (2006), outlines the important steps involved in the planning, implementing and analysis of case studies. It is Stake's belief that most individuals who conduct contemporary qualitative research " ... hold that knowledge is constructed rather than discovered" (Stake, 1995, p. 99). This epistemological stance aligns with the theoretical framework of this study, which is founded in inquiry-based learning theories. As outlined by Creswell (2016), there are four possible worldviews that qualitative researchers possess, and this research is centered around the Constructivist Paradigm (see Theoretical Framework), which aligns with Stake's case study research methodology.

The first consideration of this research is what Stake refers to as the *quintain* (2006, p. 4). The quintain is the "object or phenomenon or condition to be studied -- a target but not a bullseye" (Stake, 2006, p. 6). Stake goes on to explain that the quintain is similar to an evaluand -- or subject -- of a program evaluation (2006). Alternatively, the quintain could be compared to a selected sport in the Olympics, like swimming; it is a specific focus, but there are different race distances and formats that are all considered swimming despite their differences. The quintain in this research is the perceived abilities in STEM activities, of three girls in a week-long March Break camp. The individual cases that are considered in the qualitative multi-case study will be studied to learn about their "self-centering, complexity, and situational uniqueness" (Stake, 2006, p. 6).

Although the sample size (n=3) was small, purposeful sampling (Patton, 2002) was implemented when choosing the participants considered for this cross-case analysis. The benefit of this method for case selection is outlined by Flyvbjerg (2010):

> When the objective is to achieve the greatest possible amount of information on a given problem or phenomenon, a representative case or a random sample may not be the most appropriate strategy. This is because the typical or average case is often not the richest in information. Atypical or extreme cases often reveal more information because they activate more actors and more basic mechanisms in the situation studied. (p. 229)

Although there were eight potential case study prospects, the nature of the camp setting created a limitation on the data available for each case. This camp was voluntary and, because it was part of a larger study, the campers were not required to interact with any one technology. As a result, I could not force inorganic interactions between the girls at the camp, and the technologies that we made available to them. Ultimately, that limited the data sources for five of the girls that attended the camp.

The three girls that were chosen to focus on in this thesis provided rich, insightful data and that created a narrative that could be studied in the context of a cross-case analysis. However, these case studies should be considered particularistic, which is defined by Merriam (1998) as "case studies that focus on a particular situation, event, program or phenomenon" (p. 29). This methodology aligns with Clifford Geertz's theory (1973) of thick description, which suggested 'not to generalize across cases but to generalize within them' (Geertz, 1973, p. 26). Implementation of thick description requires dense, specific descriptions and explanations of social interactions (Harrison, 2013). These descriptions contribute to uncovering the cultural significance that lies beneath the social interactions (Harrison, 2013). This thesis focuses on the participants, in the context of a week-long camp, and as such, the findings cannot be generalized. This leaves room for future research in other contexts.

Data collection in this study was varied and pulled from a number of several different sources. These sources included Pre-Study Surveys, which helped to determine the initial perceived abilities in STEM for each of the participants, as well as observations recorded as Field Notes, Daily Reflections, Digital and Physical Artifacts, and post-study data collection including Individual Interviews, a Focus Group Interview, and Follow-up

Interviews, done a year after the camp ended. Throughout the camp, I observed interactions with others, conversations that participants had with both camp leaders and other camp participants as well as how the participants of the study interacted with the technology. Daily, participants were asked to reflect on prompts that addressed the focus of each day. To collect these reflections, participants utilized the iPad app SeeSaw. Open-ended, semi-structured interviews and post-study surveys were also utilized as the camp came to a close.

The data that were collected in this research were analyzed using two approaches, including deductive content analysis (Mayan, 2009) and cross-case analysis of coded themes (Hull & Katz, 2006). The specific components of each of these approaches is expanded in the Data Analysis section below.

4.2 Participants

This research was born from a desire to learn more about the impact that learning STEM through IoT and from women mentors, has on the STEM self-efficacy for three different girls. This study focused on the interactions and learning of the participants, who varied in ages between 11 and 13. Each of the participants identified as girls and had a pre-existing interest in STEM, thus their participation in the camp. Each of these participants were given pseudonyms: Alannah, Simone and Katie. Each of the participants lived in the Greater Toronto Area (GTA). The summary of each participant can be found in Table 4.1.

Table 4.1
Summary of Participants, their chosen tech and project overview

Pseudonym	**Age**	**Gender**	**Chosen Tech for Passion Project**	**Passion Project Overview**
Alannah	13	Female	littleBits	Cell phone holder for the car (similar to breathalyser for those who gaining driving privileges after driving under the influence); the goal is to prevent using phone while driving
Simone	11	Female	3D printer & Arduino	Trigger sensors placed on a mat for individuals who participate in gymnastics; meant to help people learn to do a back bridge by giving feedback on hands and feet placement.
Katie	12	Female	Arduino	An alarm that is coded to help individuals when using a screen; using the 20:20:20 rule to help people reduce strain on their eyes as they work with technology.

Before the camp started, advertising and recruitment included social media blitzes with information about the camp (see Appendix A), as well as emails to contacts who had previously demonstrated interest in a technology-based camp, for their child(ren). Before and during registration, parents and participants were made aware of the research component of the camp, and research was approved by Ontario Tech U's Research Ethics Board (REB #15-094). Both guardian consent and participant assent were sought and approved for a number of different aspects of the research, including the presurvey, interviews, photos, video and observations, and any digital or tangible artifacts. The participants had the freedom to choose which sources of data they consented to be used in the study.

4.3 Environment

In order to gain insight into the girls' identities, a week-long March Break Camp was conducted at Ontario Tech University's Faculty of Education, in Oshawa, Ontario. The March Break Camp was called *Changemakers* and focused on social change and what young students can do to make a change in their worlds. Both girls and boys were enrolled in the camp and ages ranged from 6-12. Throughout the week, each day focused on a different topic (see Appendix D), which helped students to think about their experiences in life and how they might be able to create and utilize technologies to solve a problem that they encounter either daily, or often.

Throughout the week, participants utilized both online and in-person environments. Participants interacted with MacBooks, iPads and other technologies. The whole group of campers (including participants of this study) were together all morning, so both boys and girls worked together as they learned about the technologies. In the afternoon, the girls were split from the boys for at least an hour daily, to interact with the technology and plan their passion projects in an all-girls environment. Each of the participants in this study worked either on their own passion project or with another girl.

In addition to the technologies and other campers that the participants encountered, the camp was led by mostly women mentors (there was one man who assisted in the delivery of content periodically). Three women graduate students (including myself), in addition to the Lab Director and a small group of Bachelor of Education students, helped the participants innovate, plan and ultimately, create their passion projects.

4.4 Data Collection

Over the span of the five-day camp, data were collected through a number of different sources, each of which provided different insights into the perceived STEM abilities of the participants. In order for qualitative case studies such as this to be reliable, it is imperative that the "researcher collects many forms of qualitative data" (Creswell, 2013, p. 98). This thesis implements Creswell's recommendation and involves the collection of data from a number of sources, including surveys, interviews, reflection journals, field-note observations, videos, and digital and tangible artifacts that the participants created.

4.4.1 Pre-survey

The pre-survey (see Appendix E) consisted of 19 questions and contained a combination of Yes/No and short answer questions. The pre-survey was implemented with the intention of establishing a baseline understanding of each participant's self-efficacy using technology and engaging in STEM activities, before the start of the camp. The survey asked students about their conceptions and belief of ability in STEM, interest in STEM, future career paths, demographics and knowledge of IoT. This survey took the students approximately 20 minutes to complete and was completed on the first day of camp after the campers had been signed in. There were no time constraints put onto the participants and they had access to myself and the other mentors for clarity of questions, if necessary. The depth of which the participants should go into answering each question was not outlined, so participant discretion was used to help guide the detail that was included in each answer.

4.4.2 Field Notes and Observations

Throughout the week, camp facilitators took field notes and made observations of the participants. These observations were used in the triangulation of data, for data analysis. External observation was an important tool in tracking any small, yet important, developments in the students' identities and outside variables that may have impacted their ability to express their identities.

The research lab where the study was conducted is equipped with in-ceiling cameras and audio technology, which allowed ongoing observations throughout the day. This enabled me to gain insights into the participants' engagement and experiences, without the obtrusive nature of the camera. I was able to witness and analyze candid conversations between the participants and other campers, as well as other facilitators.

4.4.3 Daily Reflections

Participants were asked to reflect on their learning experiences each day (prompts can be found in Appendix B). They reflected in their *Digital Design Journals*, which utilized the iPad application SeeSaw to create written reflections, video reflections and capture images of their progress for the day. Daily reflections were individual and the participants were given the freedom to spread out so that they were not impacted by the reflections of the other campers around them. These reflections gave insight into their feelings and understanding of the activities that they encountered for the day, and helped to gain a more in-depth understanding of the students' work processes.

The progress was documented throughout the week, which resulted in a timeline that the participants recorded in their *Digital Design Journals*. This timeline, along with the words that they chose to use to express their progress, were analyzed within the triangulation of data to help track the participants' mindsets as the week progressed.

4.4.4 Participant Artifacts

The weeklong camp required the participants to create artifacts, both digital and tangible, which were determined by their passion (i.e. passion project). I analyzed how the students utilized their newfound skills and knowledge to apply their STEM capabilities in the creation of their passion projects. All of the participants created prototypes of their projects, but each utilized different technology and had different end goals for their project and it was important to analyze why they decided to use their chosen technologies.

4.4.5 Interviews

At the end of the week-long camp, the participants took part in open-ended, semi-structured interviews, both in a group setting and individually. These interviews helped me gain a more in-depth understanding of the impact that the camp had on the participants' perceptions of themselves and their abilities in STEM. The individual interviews helped me to discern their personal ideas and understandings without the impact of other peers. Each interview was organized as a conversation with one of the mentors but was structured by set questions that can be found in Appendix F. Participants in the camp were asked to participate in the interviews and interviews were strategically planned during 'down' times. However, time was a valuable resource as the week came to a close and one participant in this case study determined that she could not afford to lose time working on her passion project. The participants were asked 8 open-ended questions in the individual interviews. Although the questions were used as guiding prompts for the conversation, participants had the freedom to expand and deter from the questions, when they deemed necessary. The conversation as a whole was demonstrative of the participant's learning, so comments that deterred from the set questions, were welcomed. Interview times were an average of 8 minutes.

4.4.6 Focus Group Interview

In the group interview, the participants had the opportunity to bounce ideas off of other campers and reflect on their learning and experiences in the context of a group. All of the campers who identified as 'female' were asked to partake in the focus group. In light of the focus of this thesis, only the girls were asked to join the focus group. The demographic of this research is girls aged 10-13, so in attempts to get genuine reflections, a concerted effort was made to help the girls feel comfortable to share their learning. There were 8 girls who agreed to join the focus group and all three of the case-study participants (Alannah, Simone & Katie) were present. In the group setting, the participants were asked 15 questions (see Appendix G), and the length of the interview was just under 19 minutes.

Although I had specific questions that I was interested in having answered in the group interview, I allowed the conversation to free-flow. Similar to the individual interviews that were conducted, any input from the participants was deemed indicative of their learning. Both the individual interviews and the focus group were recorded using audio and video equipment and they were later transcribed, coded and analyzed for themes.

4.4.7 Follow-Up Communications/Virtual Interview

In addition to the data collected over the course of the week-long camp, I also reached out to the participants of the study 76 weeks (~1.5 years) later, to gain some long-term insight into how the camp may have impacted their STEM identity. The girls were asked a series of questions, found in Appendix H. This was a critical component of the research project because it gave me insight into the potential longer-term impact that the camp had on the participants' perceived STEM abilities. Through the capabilities of technology, we were able to meet virtually (in person was not advisable due to the ongoing pandemic) and debrief about how the camp may have impacted their motivation to learn STEM, their confidence when learning STEM and, in turn, their perceived STEM abilities.

4.5 Procedure/Research Design

This research project was a part of a larger project, as mentioned above, and as such, it took considerable planning time. Leading up to the March Break, the research team for the larger project met a number of times, to ensure that the research questions/objectives were central to the implementation of the technologies and activities. Each activity was intentional and meaningful for the overall research goals.

In addition to the planning, the research team utilized social media platforms, including Twitter, Instagram and Facebook to promote the project. These social media blitzes were critical to the success of the research; however, they also contributed to an unavoidable bias, because of the nature of those who might be interested in a technology-based camp. This is something that was considered a great deal, but was determined inevitable. In addition to the social media blitzes, research team members also reached out to teachers and other contacts that might be interested in sharing the camp information. This camp was partially funded by a number of stakeholders, and as such, we had some flexibility with subsidy money. We were able to offer free seats in the camp to four of the campers, which helped to neutralize the financial burden (and in turn, the socio-economic bias of the camp), as there was a camp registration fee of $169.50, including taxes.

The camp was not limited to just girls, because the larger research study did not focus on one particular gender; however, in the planning stages, the gender of campers was taken into account. To create a different environment for the participants of this study, the girls and boys were separated for a portion of the day, while they worked on their passion projects. The intention was to determine whether the girls (and participants of this study) worked differently, or felt differently about their STEM abilities when working with other girls. One aspect that was considered here was the participant's likeliness to take on a leadership role (i.e., helping other campers, showing other campers how to use specific tech, etc.). Leadership requires self-confidence (Kolb, 1999) so this action (or inaction) was used to help determine their confidence in these areas, which can be an indicator of self-efficacy (McCormick et al., 2002).

The camp was planned in daily segments, as we tried to keep a similar layout of the day. Although it was planned with general outlines for each day, it was important to researchers to allow for an ebb and flow that shifted, depending on the needs, interests and passions of the campers. Each day started with an energizer/ice breaker for the campers. These activities aligned with Gibbs et al.'s *Tribes* (1994), and aimed to create an inclusive environment for the campers, in which they felt safe taking risks. Following the ice breaker, campers were led through a guided learning experience. The focus of each day changed, and these foci are outlined in Appendix B. Following that, the campers were introduced to a technology tool that afforded the personalization that IoT requires. Campers learned about and had access to: programmable robots (including Sphero, Dash, Cue, Vector), various coding applications (including those on the MacBook and iPad), Google Home, Amazon Alexa, Micro:bits, Arduino, Little Bits, 3D design software and Cricut design space. In addition to the technology-based activities and learning that the participants engaged in, they were also exposed to tangible 'making', including the creation of personalized t-shirts (some of which were created with passion projects as the focus), the use of building materials (such as cardboard, Makedo materials, 3Doodlers). The campers had access to a number of different supplies, which they utilized to bring their conceptualized passion projects to life.

The central concept that has been mentioned throughout the research design is the Passion Project. Throughout the week, participants were required to conceptualize, plan out, create prototypes and bring to life their passion project. These passion projects were introduced through the use of a number of children's books - including *Weslandia* (Fleischman, 1999) and *Anno's Magic Seeds* (Anno, 2000). The importance of creating something for the betterment of society was central to the books that were read to the participants, which may have offered inspiration for participants when they began planning and creating their passion projects. The focus of each participant's passion project was chosen by the participant, and each of the participants had the opportunity to work alone or with another camper. Of the three participants in this study, two worked alone and one worked with another camper.

Each day, the participants had dedicated time to learn about the technologies of their choice, and develop their passion projects. At times, they learned about the technologies, with the intention of including that chosen technology into their passion project, and at other times, they explored technologies that were not incorporated into their passion project. Our approach was not prescriptive and campers were not restricted to which kind of technology they chose to use.

Throughout the design process, participants had access to 'experts' (camp facilitators). Each facilitator had a specialty, and we were able to provide additional support to campers, for that technology. Experts aimed to give participants support, while still encouraging them to work on problem solving skills as they worked through the design process. Some participants required more support than others, which will be discussed in the Findings section.

At the end of the week, campers had the opportunity to invite their parents/guardians/ families to come to the Faculty of Education to participate in a Gallery Walk, which allowed the participants to share their passion projects and demonstrate the knowledge that they gained throughout the week. Participants decided who was invited to the Gallery Walk, and they were able to explore the other campers' creations as well.

4.6 Data Analysis

This study utilizes a number of different methods for data analysis, including deductive content analysis (Mayan, 2009), and cross-case analysis of coded themes (Cruzes, 2015). Through the analysis of the data, the findings become clear. Below, I outline the data analysis procedures I used to explore each of the research questions driving the study.

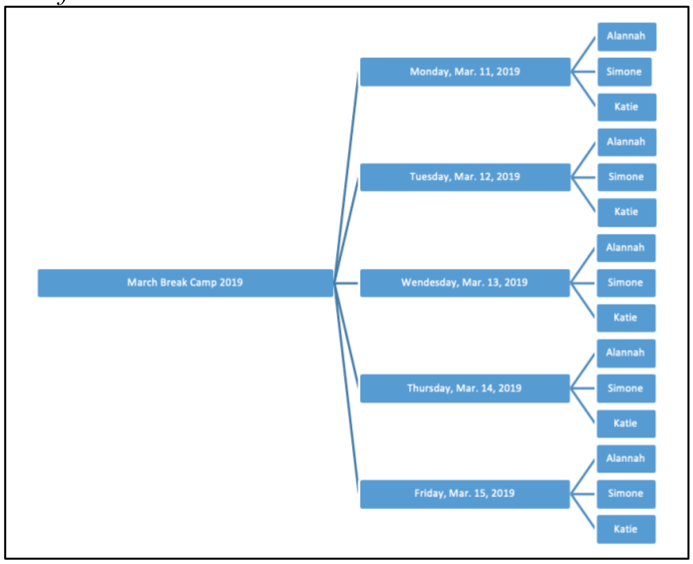
4.6.1 Deductive Content Analysis

Content analysis is a methodology that is used for studying communication symbols and messages (Riffe et al., 2014). This method of analyzing data can be used for a variety of communications (McKibben et al., 2020), so it fits well in these contexts because of the number of sources of data that are collected. The theoretical framework and previous literature that inform this research act as guiding sources for the data analysis, and these inform the use of deductive content analysis. This method of analysis is relevant when "some views, previous research findings, theories, or conceptual frameworks regarding the phenomenon of interest exist" (Armat et al., 2018, p. 220). Deductive content analysis is applicable in this context because of the known concepts that can contribute to self-perceived abilities, as outlined in earlier sections (Theoretical Framework and Literature Review). The application of content analysis requires that distinct steps are followed. The steps followed in this research have been outlined below:

Step 1: Data Collection and Sorting

Data were collected and sorted from the various sources, including survey responses, written reflections, video reflections, interview answers, candid conversations, digital and photos and videos of tangible artifacts. The data were sorted into chronological order and placed in folders for each of the participants. The flow of organization can be seen in figure 4.1.

Figure 4.1
Organizational Flow of Data



Step 2: Analysis of Content for Themes

Once the data were organized, I sifted through all of the participants' survey responses, video transcriptions, researcher's field notes and daily reflections for keywords that related to motivation, engagement, confidence and ultimately, self-perceived ability. Motivation and self-perceived ability have been previously contextualized. For the purpose of this research, engagement can be defined as "the extent to which a learner applies a level of attention and curiosity to a situation to achieve a desirable result" (Maas & Hughes, 2020, p. 240). Troubleshooting and problem solving are major indicators that, in this research, are used to identify engagement.

Step 3: Coding for Relevant Theories and Research Findings

To guide the research findings, specific aspects of identity formation and pursuance of STEM learning were considered. The concepts that have been identified for this research, are motivation, engagement and self-perceived ability.

This research involved transcription of videos and listening to the conversations and answers given in the interviews and focus group, to discern how the participant's motivation was impacted by the personalized options that IoT provides. From those observations, key concepts were pulled and analyzed. While searching through the various observational sources, I searched for keywords and observations that helped to demonstrate a shift in the participants' perceived STEM abilities, within the realms of motivation, engagement and self-perceived abilities. I looked at the language they used, the way they engaged with the technology and with other campers, and whether their attitude toward the activities shifted throughout the week.

Examples of specific terms, actions or artifacts that were identified to relate to either motivation, engagement or ability, as well as which concept, they were related to, can be found in Table 4.2, and have been determined from three sources: the data, previous studies, and theories.

Table 4.2
Observations Considered for Deductive Content Analysis

Concept	Observation
Motivation	- Positive attitude, participation, attempting new challenges (Resnick et al., 2009a) - Setting goals, persistence in tasks (Miller et al., 1993) - Curiosity (Tucci, 2018)
Engagement	- Problem solving, asking relevant questions, critical thinking (Hughes, 2017) - Enjoyment, interest (Kim et al., 2015)
Perceived Ability	- Confidence, excitement to share (Greene & Miller, 1996) - Taking on a leadership role (Kolb, 1999) - Self-regulatory behaviour: help seeking, elaboration, environmental structuring, and planning (Miller et a., 1993; Cleary & Kitsantas, 2017)

Step 4: Checking for Coding Consistency

During the process of thematic coding, the data were constantly reviewed to ensure coding consistency (Zhang & Wildemuth, 2009). To ensure consistency, I looked for similar themes between data sets, and aimed to ensure that these themes were being coded in a similar manner.

Step 5: Drawing Conclusions

Once the data were coded it was possible to draw conclusions by relating the categories. To gain insight into the intersections of the lived experiences of the participants, the various data were triangulated. Data source triangulation involves the comparison of similarities and differences between the data sources, (i.e. the different participants and their processes, reflections and creations), in an attempt to develop a clearer understanding of a phenomenon (Patton, 1999). To increase the validity of this research, three case studies were considered for cross-case comparisons, and multiple sources of data were considered, for verification of themes.

Step 6: Reporting Results

Once themes were distinguished and conclusions were drawn, results were reported with a balance of description and interpretation (Zhang & Wildemuth, 2009). Descriptions were used to contextualize the specific cases, whereas interpretations were utilised to help interpret the interactions between theoretical understanding and STEM identity formation.

Chapter 5. Findings

The findings of this research include some anticipated information, as well as some new insights into STEM identities of a group of girls who attended a March Break camp entitled “Changemakers”. The camp focused on social change and the implementation of the Internet of Things as campers addressed the real-world concerns that they witness in their lives. The nature of the findings from this camp are qualitative. Data were collected through candid conversations and observations, written reflections from participants, open-ended interviews, a focus group interview and survey responses. Data were then triangulated for common themes, as outlined in detail in the Methodology section. The overarching research questions that helped guide the research include:

1. How might a week-long March Break Camp impact the development of a young girl’s identity as it relates to self-perceived abilities in STEM?
2. What impact, if any, does teaching STEM through the use of the Internet of Things (IoT), have on a young girl’s STEM identity?

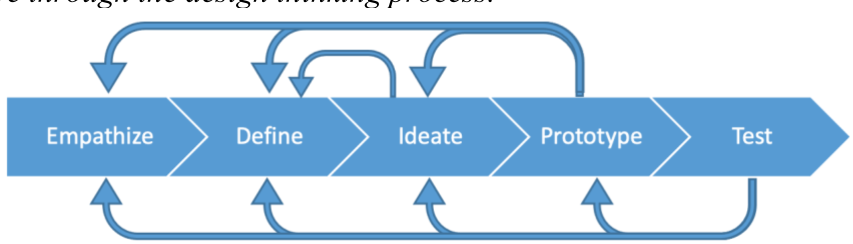
Following data analysis, two main themes that emerged from this research were: a passion for helping others as a motivating driving force for the participants to engage with STEM activities, and the role that IoT played in promoting participant confidence and engagement with STEM exploration. To set the stage for the role that engagement plays in the findings of this research, it is critical to define it. Hummell et al. (2018) defines engagement as “a qualitative level of interaction with content, activities, and people that involves students' interests, curiosity, and passion. Engagement requires students to use their own ideas, understandings, and emotions in tasks that are meaningful to them and can result in powerful generative learning” (p. 484).

To frame the findings in a way that is guided by these main themes, a design thinking framework was simplified and implemented. Design thinking has been defined as “intentional acts that lead to the creation or improvement of products, services, and experiences” (Koh et al., 2015). This camp utilized this concept, as campers learned about citizenship and stewardship of the earth, which was then used to frame how they learned and interacted with technologies. As outlined by Alhamdani (2016), a design thinking framework follows a non-linear, but a stepwise progression, through the following steps:

1. Empathize: see how people feel about an issue
2. Define: information from step 1 is used to identify a problem
3. Ideate: conceptualize solutions to the problem
4. Prototype: the use of arbitrary materials to create an example product of their solution
5. Test: using the prototype, a working product is created to help with the solution

This process is often effectively demonstrated by a graphic, similar to the one in figure 5.1.

Figure 5.1
The iterative design process, demonstrating various routes that an individual could take as they move through the design thinking process.



From each step of the process, an individual who is engaged in the design thinking process can move backwards to previous steps, as they learn more and tweak aspects of their creation, but they must start at step one. An example of how this may happen, is when one moves from the definition of their problem to the ideation of their solution, they may recognize an additional concern that is related to their approach in making a solution, so they would have to go back to the definition step of the process, to ensure their newly considered variable is incorporated into their definition of the problem.

This process is often utilized in engineering and technology research (see Hughes & Morrison, 2021), and as such, it will be implemented in this thesis to guide findings. However, because the timeline and sophisticated resources available to the camp was limited (such as the ability to create a working and ready to implement test creation), and because this research is not focused on the process of how the participants explore, but instead, the outcome of the exploration, the design thinking process has been simplified into the following steps, with examples of guiding questions:

- Understanding: What is a problem that you see in your everyday life? Are there current solutions to this problem? Why does it matter to you?
- Exploring: What are some solutions that are already available? Which technologies are implemented? How can IoT be used to help solve this problem? Are other technologies needed to help? Who would use your creation? What materials are needed for your prototype? How big will your prototype be?
- Creating: What knowledge do you need before you can work on the creation component? Do you need support to create your prototype? What kind of support?

As previously mentioned, the findings of this research have been organized into the following: understanding the problem, exploring the problem and creating a solution. Each section begins with a general overview of how that section's respective theme impacted the camp in a broad, general context. Then, that theme is considered through the lens of each of the three case studies. As mentioned in the Methodology, data that were collected throughout the duration of the week were triangulated from a variety of sources, including the pre-survey responses, participants' daily reflections, information from individual interviews and the focus group interview and researcher field notes. Each of the three participants provided varying levels of detail through the different data collection methods and as such, some data were overt and required no additional analysis (i.e. a participant stating that they felt more confident with the technology at the end of the week) while other data required more digging to flesh out the idea (i.e. the actions of the participant indicating that they were more confident, but not overtly stating that).

5.1 Understanding the Problem

From the onset of the passion projects, it was clear that each of the participants had very specific motivators that helped them navigate how they innovated. Although the specific motivating factor differed from participant to participant, the main theme that arose from the data were the interest in protecting the Earth and helping others. Each of the participants sought out an understanding of the technologies presented to them, in attempts to address issues that they identified in their lives. The participants demonstrated selflessness, or empathy, for the things and people around them. The importance of passion in the passion project is demonstrated in the way that the participants interacted with the STEM activities. Although some of the activities were prescribed (as when the campers were initially introduced to the technologies), for the majority of the week activities were planned that allowed campers to pursue their passions. All three of the participants aimed to understand a problem that was innately connected to helping others.

The participants' chosen passion project, as well as limited demographic information, is provided in table 5.1.

Table 5.1
Summary of Participants, their chosen tech and project overview

Pseudonym	Chosen Tech for Passion Project	Passion Project Overview & Goal
Alannah	littleBits	Cell phone holder for the car (similar to breathalyser for those who gaining driving privileges after DUI); the goal is to prevent using phone while driving
Simone	3D printer/arduino	Trigger sensors placed on a mat for individuals who participate in gymnastics; meant to help people learn to do a back bridge by giving feedback on hands and feet placement.
Katie	Arduino	An alarm that is coded to help individuals when using a screen; using the 20:20:20 rule to help people reduce strain on their eyes as they work with technology.

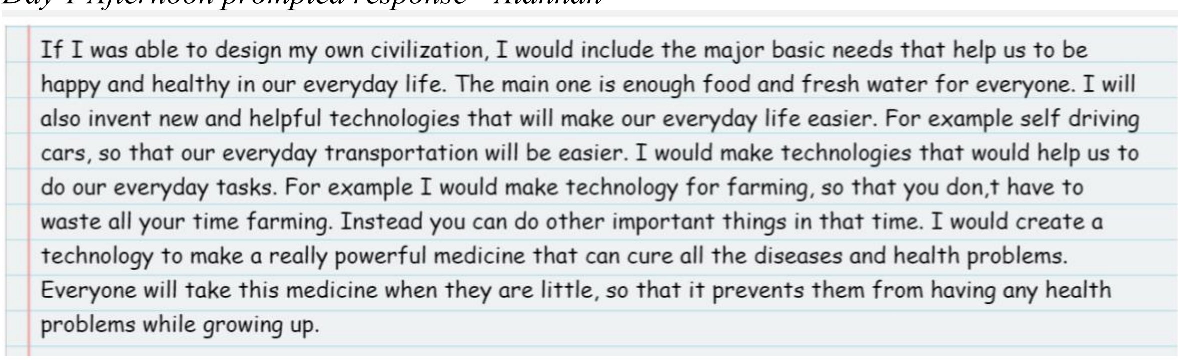
5.1.1 Alannah

From the start of the camp, it was clear that Alannah was interested in helping others. Alannah used words such as "help", "benefit civilization" and "everyone," throughout her reflections, which all indicate her desire to improve life for others. Alannah was focused on society and making changes that would, in her opinion, make life better for her fellow citizens. In a candid conversation, Alannah was asked by one of the camp leaders/researchers about her future desires for occupations and she mentioned that she wanted to go into healthcare so that she could help others. This was reiterated in her answer to the pre-camp survey question: *Do you envision yourself pursuing a job in a STEM-focused area (i.e., engineer, scientist, mathematician)? What kind of job would you like to do when you're older?* Her response was "I want to be a doctor when I grow up. I believe that you need to work with technology in every profession/job." Throughout the week, Alannah's interest in helping others was also apparent in her daily reflections.

As seen from the reflections that follow, from days 1-3 (March 11-13), in each one it is apparent that although the prompts are different and the foci of each day were different, Alannah's responses held the common theme of helping others. Following the activities of day 1, campers were asked to use SeeSaw to reflect on the following prompt: *If you were able to design your own civilization, what would you include? What kinds of things would be needed so that everyone could be happy and healthy? What kinds of technology would it include?* Alannah's written response can be found in Figure 5.1. The response that Alannah constructed demonstrates an innate desire for there to be equity in society. She begins by explaining that the basic needs of all humans are fresh water and food; both things that can be scarce in certain areas of our society – both geographic areas and in terms of groups of people (ie. lower socioeconomic status). She states that "[t]he main [need for people to be happy and healthy] is enough food and fresh water for everyone." Alannah then makes a connection between social equity and using technology to achieve said equity - although, she does not touch on how technology can help achieve her first goal of providing food and fresh water for all. She moves on to talk about how she wants to create a medicine to “cure all the diseases and health problems”. She does not indicate any one disease or health problem that she deems most important (i.e. cancer), rather, she wants to help all people suffering from diseases.

Similar to day 1 reflection, on day 2, campers were asked to reflect on SeeSaw, using the following prompt: *What did you discover about the Internet of Things (IoT) today? What tools did you most enjoy using? What kinds of things could we make with these tools that would benefit the civilizations we talked about yesterday?* Figure 5.2 is a screenshot of Alannah’s response.

Figure 5.2
Day 1 Afternoon prompted response - Alannah


If I was able to design my own civilization, I would include the major basic needs that help us to be happy and healthy in our everyday life. The main one is enough food and fresh water for everyone. I will also invent new and helpful technologies that will make our everyday life easier. For example self driving cars, so that our everyday transportation will be easier. I would make technologies that would help us to do our everyday tasks. For example I would make technology for farming, so that you don,t have to waste all your time farming. Instead you can do other important things in that time. I would create a technology to make a really powerful medicine that can cure all the diseases and health problems. Everyone will take this medicine when they are little, so that it prevents them from having any health problems while growing up.

In this response, Alannah writes about the use of technologies to help combat global warming -- an issue that is threatening life as we know it on Earth. She states that “with the help of micro:bits, you can turn the heater down when no one’s home. Not only are you saving your money, you are also saving the earth by not using energy.” Alannah learned about the technologies, then demonstrated how these can be applied to combating Climate Change, which is exactly what she says we should do: “[w]e live on this earth, we should learn, understand and take care of our earth.” The importance of using technology to help us live this way is seen clearly through her application of micro:bits to help save energy.

Following day 3 activities, campers were prompted, on SeeSaw, with the following: *Why did you choose your project and/or goal for the week? How do you think your creation could help improve other people's lives? Or improve a civilization? Do you think the Internet of Things (IoT) is a good thing or a bad thing? Why? What are your "next steps" for your invention? Are there any other maker tools that would help?* Figure 5.3 is a screenshot of how Alannah's response coincides with her earlier responses, shedding light on her innate desire to help society.

Figure 5.3
Day 2 Afternoon prompted response - Alannah

Today I learned about the Internet of Things and I really like it. I discovered that Internet of Things helps us to do our everyday task easier. Technology's like micro:bit, little bits and Arduino are really useful. Today I learned that u can control Micro:bits and Arduino using your phone. I enjoyed using micro:bits the most. I really like Arduino but I feel like I understood the micro:bits more and had fun using it. I coded a lot of things using the micro:bits. For example: smiley face, sad face, watch, heart, name tag and a die. We can make a lot of useful things with these tools that would benefit the civilization. For example, with the help of micro:bits you can turn the heater down when no ones home. Not only you are saving your money, you are also saving the earth buy not using energy for no reason. There is a lot of bad stuff happening to our earth. For example climate change, global warming, pollution and etc. We live in this earth, we should learn, understand and take care of our earth. We should try to prevent or help to make this earth a better place.

Later, when Alannah was asked about her Passion Project, she indicated that she wanted to create something based on a school project she had recently done. Her idea had been primed at school; however, this camp gave her the chance to expand her idea from a concept to a prototype. As seen in figure 5.4, Alannah indicated that when doing research for her school assignment, she learned that " ... more people are dying because of texting and driving than drinking and driving. And, for [her] that was so crazy." This was clearly the motivating factor for her. She goes on to talk about her passion project, which is a device to prevent people from texting and driving. She states:

I want to prevent texting and driving because people who text and drive are not only putting their lives in danger, but also putting other people's lives in danger on the road. I believe that my creation could help improve other people's lives ...

Alannah's focus on societal issues is a motif that is seen throughout her work, reflections and candid conversations.

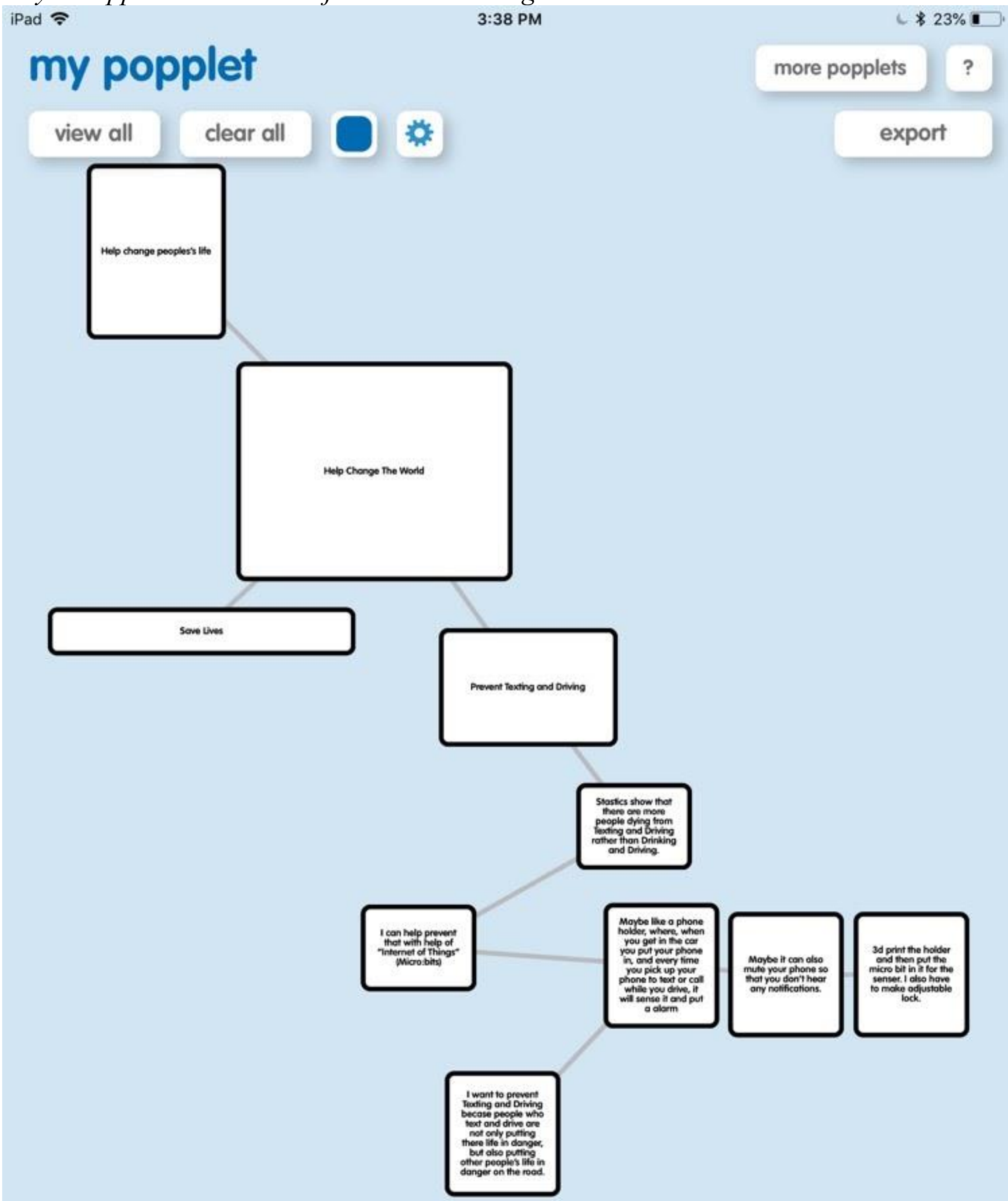
Figure 5.4
Day 3 Afternoon prompted response – Alannah

For my passion project I decided to help change the world. Recently, I had to do a art project for art class in school. I had to do printmaking. My print was a hand holding a phone and in the phone, it was written, "DON'T PUT ME DOWN". I did this to show how the phone is controlling people, rather than people controlling the phone. I also had to do a reflection on it. While doing the reflection, I found out that there are more people dying because of texting and driving than drinking and driving. And, for me that was so crazy. So I decided to make something that will prevent people from texting or checking their phone while driving. My plan is to make a phone holder for your car. So that every time you get into your car you have to put you phone in the holder/cup. And, every time you go to pick up your phone to check or text while your driving, it will sense the movement and put in alarm. I will use a micro bit to sense it and put an alarm. I want to prevent texting and driving because people who text and drive are not only putting their lives in danger, but also putting other people's lives on danger on the road. I believe that my creation could help improve other people's lives and improve the civilization. I think the Internet of Things is a really good thing because it improves and helps us to do our everyday tasks easier.

As she moved from conceptualizing her project to planning her passion project, Alannah began with brainstorming. Campers were asked to start brainstorming on Popplet. In her planning, it is very clear that central to her ideas are the needs of others. Figure 5.5 indicates that "Help change the world" was where she started her ideas. "Help change people's lives" and "save lives" were also indicated on the brainstorming.

Figure 5.5

Day 3 Popplet - Passion Project Brainstorming Alannah



At the end of the camp, during the post-camp interview, when Alannah was asked about what kinds of technology she learned about throughout the week, she replied: " ... technology that connects to the internet and makes our life easier. It helps us to do our everyday tasks more easily. When asked about why Alannah chose to focus on cell phones, she responded:

> ... kids in my school, I see them, I'm working and they're on their phone fooling around. And when teachers are talking, they're on their phones under their desk, and it's actually affecting them. And they're my friends, I tell them every time, 'come on, do your work', but they're always on their phone. So, it's definitely affecting their grades, their study...

The progression through various realms and concerns in society is apparent in the data that were collected; however, Alannah aims to understand the ways in which the technologies presented to her might be effective in solving problems that she can identify in our society.

5.1.2 Simone

From the start of the camp, Simone made it clear that she loved art and enjoyed creating things (at one point, she even removed what she deemed to be 'ugly' colours from the markers being used by her group, as they represented some mathematical concepts). Her initial desire to help people was not clearly obvious, but following data analysis, it is clear that she addresses issues in society as she planned a eutopia on Day 1. More on this in the Discussion. As the week progressed, Simone's desire to help others was apparent and much more overt.

Following Day 1 activities, when campers were asked to reflect on SeeSaw, Simone demonstrated a desire to combat hunger in our society (Figure 5.6).

Figure 5.6

Day 1 Afternoon prompted response - Simone

I would add food in my civilization and bees and humans and lost of computers for everyone and and puppies and lots of candy stores and homes for the homeless and free toys and clothes and robots to decide what to where and lots of chocolate and no pollution and garbages on every street but the garbage doesn't stink also we would have teleportation cars and everything is free and we use all technology at school no papers .we would need doctors and nurses and animals and bacteria to be happy and healthy .laptops computers iPads phones earbuds VR 3Dprinters

Although her response does not explicitly state that she wants to make society 'better', she does state that she " … would add food in my civilization and bees …" In addition, she included that she would have "homes for the homeless … no pollution … we use all technology at school, no papers." She doesn't explicitly state that she is motivated by helping others, but all of these ideas demonstrate the desire to help others, in various ways. She states that she would include homes for people who currently do not have homes. She would also ensure there is no pollution and she does not want to use paper in schools.

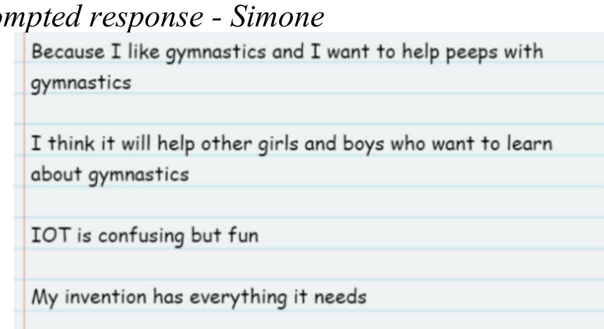
Throughout the week, it was noted that she was drawn to the more creative technologies and was driven to learn and understand them, by her own passion for art. However, that was not the only thing that drove her exploration. Early in the week, Simone became friends with another camper who shared a common interest of gymnastics, and that commonality drove Simone's exploration to understand some of the technologies that were made available to her. When Simone started planning her passion project, she shifted her thinking from helping the general society to helping a specific group of people: gymnasts.

As the week went on, Simone and her partner worked to develop a specific way that they could help gymnasts become better. Ultimately, they decided to focus on a device that could help gymnasts complete a backbend. In addition to the reflection notes on SeeSaw, candid observations of conversations between Simone and researchers echo this need to help other gymnasts. In researcher observation notes, it was stated that "[Simone and her partner] want to create something that will help people learn how to do gymnastics backbends. Initially they were thinking of a creation that they could use to hold a person's back so when you turn over backwards it would support your lower back and keep you in position." Following Day 3 of the camp, campers were prompted with the following statements:

- *Why did you choose your project and/or goal for the week?*
- *How do you think your creation could help improve other people's lives? Or improve a civilization?*
- *Do you think the Internet of Things (IoT) is a good thing or a bad thing? Why?*
- *What are your "next steps" for your invention? Are there any other maker tools that would help?*

Simone's responses were rather simple, they but shed light on the factors that motivated her throughout the week. In her Day 3 SeeSaw reflection (Figures 5.7 and 5.8), Simone wrote that "because [she] likes gymnastics [she] want[ed] to help [people] with gymnastics" and "[w]e think we can help someone else do a bridge with our project." She explicitly stated that she wanted to help others in their gymnastics abilities.

Figure 5.7
Day 3 Afternoon prompted response - Simone


Because I like gymnastics and I want to help peeps with gymnastics

I think it will help other girls and boys who want to learn about gymnastics

IOT is confusing but fun

My invention has everything it needs

Figure 5.8
Day 3 Afternoon prompted response - Simone

We think we can help someone else do a brige with are project.

5.1.3 Katie

Katie's desire to help others became apparent after the first day. At the end of day one, campers were asked to respond to the following prompts:

- *If you were able to design your own civilization, what would you include?*

- *What kinds of things would be needed so that everyone could be happy and healthy?*

- *What kinds of technology would it include?*

Katie was thorough in her response, and when mentioning the different aspects of change, she mentions the impact that each change would have on people in her civilization (Figure 5.9).

Figure 5.9
Day 1 Afternoon prompted response - Katie

If I wanted to create a civilization, I would want to add easy access to basic necessities like food and water. There would be access to nutritious foods so everyone can live a healthy happy life. I would also add many buildings for entertainment(like malls, cafes amusement parks, etc.) so people can have fun too. There would also be many hospitals, doctor clinics, and more so everyone can get well when they are ill. Obviously education is important, so i would add online school so you can learn at the comfort of your home. There would be a VR attachment that would simulate a gym or the outdoors so you can get exercise and reminders to get off the online system to socialize and get fresh air.

For technology, I would want to add transportation that runs on greenhouse gases, so it is Eco-friendly and produces less pollution. Hovering self-driving cars would be cool, hoverboards that actually hover, an Eco-friendly jet pack to fly with, and teleportation would be the things I add to make transportation easier. I would also want a scanner that can instantly heal you if you have a severe illness so everyone can live a good life. Overall, that's what I would want to add.

Katie's response states that she would "add easy access to basic necessities like food and water … so everyone can live a healthy, happy life … I would also add many buildings for entertainment … so people can have fun too … There would also be many hospitals … so everyone can get well when they are ill." Katie relates to a number of different aspects of life, and how she would improve those aspects for the civilians in her society. In this response, Katie mentions (more than once) the need for Eco-friendly alternatives to the way that our society implements transportation. She states that she would "want to add transportation that runs on greenhouse gases," remind people to "get fresh air" and implement the use of "Eco-friendly jet packs to fly with".

Katie's sentiments are echoed in her Day 2 Seesaw responses to the prompt: *What other problems can you think of that we might be able to solve through our inventions? These can be problems that happen at your school (bullying), or bigger problems in the world (people living in unsafe areas).* Katie writes about bullying interventions and the use of IoT to help people in various unsafe living conditions, to improve their quality of life (Figure 5.10).

Figure 5.10
Day 2 Afternoon prompted response - Katie

In the world, we could solve many problems like bullying, monitoring the home for dangers, monitoring food and water supply, etc. If someone is living in an unsafe area, we could use inventions for security like cameras that detect motion while you are gone or if we get very advanced, it can detect an unfamiliar face in the home, etc. Like in the IoT video, we could make inventions that monitor the house if a garden is dehydrated or the door is unlocked. In developing countries, we could have tech where it monitors food and water supply so instead of after work seeing that you ran you of food, you could see that you ran out and do out during the day. For bullying, technology could simulate situations and teach you to respond to them.

These problems are important to me because many people in the world experience these problems, and even people close to me. Making these inventions could help many people in the world.

Mar 12, 2019

Katie writes that "[t]hese problems are important to [her] because many people in the world experience these problems, and even people close to [her]. Making these inventions could help many people in the world." This reflection verifies her desire to help others.

As she narrowed her focus from generally helping others, Katie's chosen passion project aimed to help people through the creation of a timer that tracks screen use for users. Once the user has used the screened device (i.e. computer, iPad), the timer goes off, reminding the user to rest their eyes for 20 seconds, by looking at something 20m away (using the 20:20:20 rule).

As the week progressed, Katie's motivation remained consistent, which is demonstrated in her Day 3 Seesaw reflection. Campers were prompted with the following questions:

- *Why did you choose your project and/or goal for the week?*
- *How do you think your creation could help improve other people's lives? Or improve a civilization?*
- *Do you think the Internet of Things (IoT) is a good thing or a bad thing? Why?*
- *What are your "next steps" for your invention? Are there any other maker tools that would help?*

In response to the second prompt, Katie mentioned that "[her device] reminds [people] to be more careful with [technology] becoming so common in everyone's lives," shown in figure 5.11.

Figure 5.11
Day 3 Afternoon prompted response - Katie

I chose my project because I am very passionate about programming and technology. A project that involves programming a device that can improve the experience of using technology would be perfect to work on with Arduino and other tools.

I think my project can improve other people's lives because more people in the modern world use devices or technology, so the problems of using technology become more common. The problems can affect the human body! My invention will remind people to take a break from staring at a screen for so long , and also remind them that something as simple as staring at a screen can affect their vision! It reminds them to be more careful with something becoming so common in everybody's lives.

Right now, I am trying to connect my Arduino device to devices so it can go off every 20 minutes after the device is being used. My next step is to start adding on multiple lights and programming my device to go off at specific times. I am using an Arduino kit to continue my project and a laptop to program.

Katie's rationale demonstrates a focused and specific goal, which results in helping others, while applying her passion of coding.

Katie echoed this sentiment at the end of the week, in an interview with researchers. When asked *What was your motivation for [the project]?* Katie responded with the explanation that

> [w]hen [we were told] that it could be anything we want, anything we're passionate about, I thought of first technology because I like technology. And, I wanted something that could kind of … I thought of the conseq-- not the consequences, but the problems of technology and it's becoming so common, and like … eye strain, sore eyes, is also becoming common too, so I thought we could make something for that.

Again, she acknowledges the negative components of technology in our society and attempts to create a plan to combat the negative effects, to allow for the benefits of technology to continue to prevail - which benefits those who are using it.

Although this issue that she tackles throughout the week is smaller scale, Katie recognizes the potential that "infinite coding and infinite technology" could afford. During the interview that she participated in at the end of the week, when asked *what would you want to do with [your project] if you could blow it up, and do anything with it?* She responded with:

> I could improve my project, but by then a lot of people might have improved it already, 'cause it's not really a big project that could help society, it's just like a notification, but I think in that situation where I had all the money, all the resources, I'd do something else to help the world, instead of like a small notification … If I had infinite coding and infinite technology, I could do something that could … not take our problems away, but reduce the amount of greenhouse gases in the atmosphere and use that to produce something useful. Yeah. So, take a problem, make it useful … kind of thing.

5.2 Exploring the Problem using Internet of Things

Following the "Understanding" phase of each of the campers, was the "Exploration" stage. As participants learned about Citizenship and Stewardship of the Earth, through the various activities, they narrowed their focus on specific issues that they deemed important. All campers were given the opportunity to explore the various technologies that were provided for them, through both instructor-led activities, as well as personal choice, interest led engagement. As the participants explored the different technologies, it became apparent that they became more confident in their interactions with the specific technologies that could be of use to them as they transitioned to the "Creating" stage of the process.

The exploration stage for each participant looked different because they chose to explore different technologies, as they pertained to their passion project focus. However, as the participants engaged with each of their specific technologies, it was clear that they began to take on an 'expert' role, as they began to help others problem solve and learn the technologies that they were exploring.

Central to the camp organization the methodology of this thesis (see Methodology), is the implementation of IoT as the participants engage in learning technology. As previously defined, IoT is the network interconnection of everyday physical objects (Xia et al., 2012). In general, IoT was central to the shift that participants saw in their perceived STEM abilities. Following the pre-study survey, it was clear that the participants of the study had an idea of what IoT was, but it was a very limited understanding. All three participants responded with "maybe" when they were asked whether they had ever heard of "Internet of Things" or "Smart" home/devices. When asked to expand on their understanding, two of the participants went on to describe their understanding, explaining that they knew what Smart home devices are, but had no understanding of Internet of Things. The full responses to the various pre-camp survey questions can be found in table 5.2

Table 5.2
Pre-survey questions and responses about IoT

Question	Alannah Response	Simone Response	Katie Response
Have you ever heard of the “Internet of Things”? Or “Smart” homes/devices?	Maybe	Maybe	Maybe
What do you know about it? What do you think it means?	I know what smart phone and TVs are but I don't know what "Internet of Things" are.	I don’t know.	I never heard of "Internet of Things". I think a smart device means that it is an advanced piece of technology that can help you in your daily life. (Like google home or amazon echo)
Do you believe you could use IoT to make your life better/easier/more exciting? Why/why not?	Probably, but I don't know what "Internet of Things" is maybe after I know what it is, it will be easier for me to decide.	More exciting because it is fun	I think so because it can make your life faster and make things more efficient.
Do you believe that you can create something, with technology, that could contribute to a better/easier/more fun life? Why/why not?	Yes, I believe that I can create something, with technology, that could contribute to a better/easier/more fun life because everything we do know is with the help of technology. Technology impacted on our life so much.	Yes	I think I can because I have tried brainstorming different efficient products at school for products, so I think one day I can really make a product.

As the camp progressed, it became apparent that participants became more familiar with IoT and the potential applications of it in their lives. It is important to note that the majority of the technologies that were utilized in the camp implemented were rooted in IoT approaches. These technologies included Arduino, Micro:bits, LittleBits, various robots (including Sphero and Ozobot). However, there were technologies that were made available to participants that did not implement IoT foundations, such as 3D printing, Cricut cutting machines and embroidery machines.

Participants explored the various technologies, and this exploration informed which technology they chose to implement in their passion projects. For all three participants, use of IoT was critical in creating each of their passion project. All three participants utilized sensors (an input) which dictated the output that was provided for the user. Alannah chose to focus rather exclusively on learning and implementing Micro:bits into her project. Simone also focused on learning Micro:bits, but as previously mentioned, she also really focused on the creative technologies, specifically 3D printing and the 3D doodler – both of which do not implement IoT concepts. Katie chose to focus on increasing her knowledge and ability when using Arduino. The use of IoT for each participant is summarized in table 5.3.

Table 5.3
How each Participant Incorporated IoT into their Passion Project

Participant	Incorporation of IoT
Alannah	"I wanted to create a phone holder, when you go into the car, you put your phone in, and every time you take your phone out to check your phone or text, it sets an alarm to remind you that you aren't supposed to text or check your phone while you drive."

Participant	Incorporation of IoT
Simone	“We were thinking of making a 3D printed hand, and an accordion arm, so it keeps it up, we’re testing this on a Barbie doll … The green light means they did something good; the red is for when they do something bad. Those are the coding that we would give the robot.”
Katie	“So every 20 minutes, you look at something 20 feet away for 20 seconds to reduce the strain. So mine is just, like … a reminder to remind you to look away. ‘Cause sure you could just put a normal reminder with an app, but there’s a 90% chance that you’ll ignore it. So mine is annoying enough where you’ll just look away, because it’s a light … a bright light… that’ll flash, and let’s say it’s attached to your screen … it’s really bright, so you’ll have to look away.”

IoT provides personalized possibilities for exploration and that was central to the overall effectiveness of using IoT as a vehicle for teaching and learning in these contexts. On more than one occasion, each of the participants mentioned the importance of the freedom to pursue their passion as they learned new technologies. However, it must be noted that Simone’s interactions with IoT were much less organic than the other two participants. In order for Simone to interact with the IoT technologies (specifically, Micro:bits), she was very dependent on guidance from leaders, to pursuing her passions through the IoT. For example, before she chose to code with Micro:bits, she had to have a reason that was connected to her other passions (art and gymnastics). This can be seen above, in table 5.3, where she first explains that she needed to 3D print a hand, which could then be coded. The overall importance of passion and the personalized opportunities for IoT will be explored through each case study.

5.2.1 Alannah

Alannah was the oldest camper and she came into the camp with a rather vast knowledge of different technologies. With that, she tried all the different technologies that were available to her, but she recognized her skills when using certain ones and adapted her project so that she could implement the technologies that she felt most comfortable with; she kept it within her scope of ability.

On day 2, the campers worked with an IoT technology called Micro:bits. When prompted to reflect on the question, *What tools did you most enjoy using?* using SeeSaw, Alannah mentioned her enjoyment while using Micro:bit (Figure 5.12). She stated that “Today I learned that you can control Micro:bits and Arduino using your phone. I enjoyed using Micro:bits the most. I really like Arduino but I feel like I understood the Micro:bits more and had fun using it.”

Figure 5.12
Day 2 PM Reflection - Alannah

Today I learned about the Internet of Things and I really like it. I discovered that Internet of Things helps us to do our everyday task easier. Technology's like micro:bit, little bits and Arduino are really useful. Today I learned that u can control Micro:bits and Arduino using your phone. I enjoyed using micro:bits the most. I really like Arduino but I feel like I understood the micro:bits more and had fun using it. I coded a lot of things using the micro:bits. For example: smiley face, sad face, watch, heart, name tag and a die. We can make a lot of useful things with these tools that would benefit the civilization. For example, with the help of micro:bits you can turn the heater down when no ones home. Not only you are saving your money, you are also saving the earth buy not using energy for no reason. There is a lot of bad stuff happening to our earth. For example climate change, global warming, pollution and etc. We live in this earth, we should learn, understand and take care of our earth. We should try to prevent or help to make this earth a better place.

Once Alannah had knowledge of the capabilities and limitation of Micro:bits, she took full advantage of the personalized aspects of it. Alannah came into the camp with limited knowledge of IoT. On the pre-camp survey, when she was asked *What do you understand the Internet of Things to be? How would you define it?* She responded: “They're just tools and technology that connects to the internet to make our lives easier, and improve our life, pretty much.” Although she began with a limited knowledge of IoT, her interactions with it throughout the week enhanced her knowledge of it. This knowledge guided her as she grew her passion project from an idea to a tangible object.

Alannah's ability to recognize the capabilities of IoT in her life was very apparent by the end of the week, when asked about how IoT can be implemented to make other people's lives better. To answer the question, Alannah spoke about her project, stating that:

> recently in school, I did an art project where I did printmaking, and my print was a hand holding a phone, and the phone says, 'Don't put me down', to show that the phone sometimes … people are so addicted to their phone, and the phone is literally controlling you - not you controlling the phone. The phone is saying 'don't put me down', and the phone is chained to his hand, to show that it's always on you and not letting you put it down. And also, after that, I had to do a reflection on my print, and while doing research I found out that texting and driving causes more deaths than drinking and driving, and when I saw that, it was so crazy for me. That's why I wanted to help change the world, somehow … to help change, or save lives. I always like to help people, so I was trying to find out … how can my actions help other people? So, I decided to create a phone holder, or like a cup-holder to put into your car. And every time you get in your car, you turn it on and put your phone in the phone holder. And people usually, like … they don't want to text and drive, they don't want to kill other people, they just do it unconsciously. While they're driving, they just hear a notification or a bell, and just unconsciously go to check their phone. And for not doing that … so

> every time they try to pick up their phone to check it or text, a beep will go on … an alarm … so it will sense it, and then they'll remember that they're not allowed to pick it up, and will put it back.

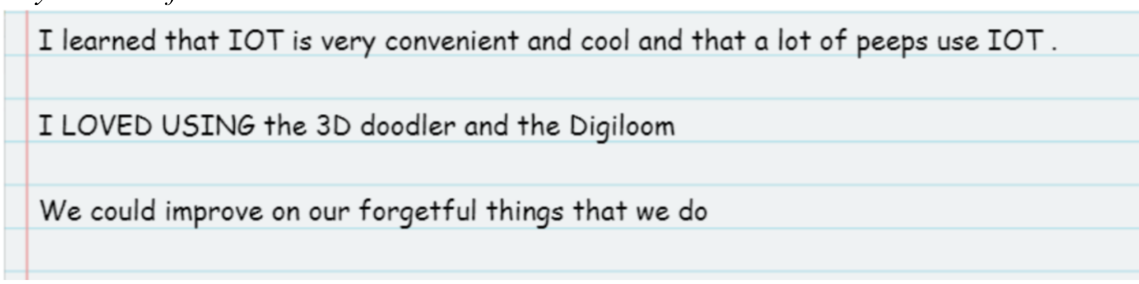
Expanding on that, when she was asked *Where did your interest in this subject start?* she responded, stating that "everyone at my school is addicted to their phone, and … that's why." Alannah came into the camp with previous knowledge about a societal issue that was important to her, and she was able to fully explore the different technologies with her end goal in mind.

5.2.2 Simone

Simone took a while to determine her passion project, and ultimately, decided to work with another camper. This was not decided until the third day of camp, and both Simone and her partner had a difficult time determining a focus, and the goal that they wanted to achieve with their passion project. Simone's project was described by researchers as "a device that uses touch sensors to help people learn to do back bridges (a gymnastics 'move'). There are 4 sensors -- two where the hands should land and two where the feet should be to ensure balance and good form when on the bridge." Simone and her partner decided that they would 3D print a hand that would demonstrate the capabilities of their prototype. Although her interest in gymnastics was what became the focus of her project, while exploring with the technology she also pursued another interest -- art.

In the pre-camp survey, Simone indicated that she enjoyed using "art technology" and that her favourite subject in school was "art [because she] like[s] to draw." Throughout the week, Simone was very curious about the different ways that she could create with technology, so that she could create 3-dimensional art. Although campers created pattern art through coding, she did not seem as engaged in those activities. She was not very engaged in the coding or mathematical concepts, but really enjoyed the 3Doodler and Digiloom -- as mentioned in her Day 2 SeeSaw reflection, when asked *What tools did you most enjoy using?* (Figure 5.13).

Figure 5.13
Day 2 PM Reflection - Simone


I learned that IOT is very convenient and cool and that a lot of peeps use IOT .

I LOVED USING the 3D doodler and the Digiloom

We could improve on our forgetful things that we do

When campers were given time to work on their passion projects, they were given the freedom to work without constant reminders to stay on task. Simone had a difficult time maintaining her focus on her passion project. When she became unengaged with her passion project, she would often use her time creating art with the 3D Doodler and bracelets with the Digiloom. She touched on this in the final day focus group interview, saying that:

> I like what we [had choice] because I feel if you didn't give us a choice, that we wouldn't have learned as much as we did, because what we did is like some of us, tried something and maybe it didn't work out, and wouldn't know that it wouldn't work out that way if we never tried -- we wouldn't know this much about technology as we do now, because we would have learned about one thing instead of exploring and trying new things … I thought it was going to be sitting on a computer all day,

> not getting much hands on but then I got here and got really excited because I found out we were building stuff. What I really enjoyed about it was that we got to play with everything after lunch and break -- it wasn't just doing our passion project. We got to explore things other than our main focus of it.

The flexibility of the camp, in the sense that the campers had the opportunity to explore and get to know different technologies based on their passions and interests, was an aspect that Simone both appreciated, and utilized. This opportunity to explore is what allowed Simone to thrive while learning technology connected to art, which ultimately led to her confidence with the technologies.

After exploration with the art-technologies, Simone found a way to combine her love for art with her passion for gymnastics, by 3D printing a hand that could be used in her project. The exploration stage for Simone was critical in her journey, however, it may have hindered her ability to complete her passion project.

Simone was the only participant of this study who did not complete her passion project by the final day. The lack of focus that Simone demonstrated likely contributed to minimal time that was used to create her passion project. Simone interacted much more with the art technologies (which was expected, as she indicated in her pre-survey that she enjoyed art technologies), as opposed to the IoT technologies.

5.2.3 Katie

When campers started creating with technology, she jumped right in. During the first day, campers were given the opportunity to learn about a number of different technologies and Katie was not hesitant to try them all, even if they were new to her. One technology that she found particularly interesting was the Arduino.

Initially, Katie was stuck on trying to make something that would have a large-scale impact. However, she indicated that "[when we were told that] it could be anything we want, anything we're passionate about, I thought of first technology, because I like technology. And, I wanted something that could kind of … I thought of the conseq-- not the consequences, but the problems of technology and it's becoming so common, and like … eye strain, sore eyes, is also becoming common too, so I thought we could make something for that."

Once she had a clear idea of what the passion projects could be, Katie had a clear idea of what she wanted to create. Katie indicated that she loved technology and she liked the challenge of learning the most complex technology that the camp offered – the Arduino. She worked independently (for the most part), and when she asked questions, they were clear and indicated a good understanding of the task at hand. Katie was self-motivated to learn the Arduino and used various resources, including instruction booklets and YouTube videos to help her learn how to turn her idea into a prototype. Katie had her end goal in mind, but the exploration phase was critical for her to determine which IoT technology would fit with her project. She recognized the importance of IoT and the freedom given to them to follow their passion through the use of IoT, stating that "I liked [the design of the camp] because it gave us more freedom to follow something we're actually interested and something we're passionate about, both of these assisted in completing the project."

Nearing the end of the camp, Katie demonstrated an enhanced understanding of IoT, stating that "it's many advanced technology devices that are connected to each other, to know you and help you." Her understanding of the applications that IoT is capable of is echoed when she was asked *do you think there's any way we could maybe apply it and make other people's lives better?* to which she responded "'Cause there's a lot of chances to personalize it. 'Cause it knows you, so you can customize it, say, when you get home, what priorities you have. 'Cause you can personalize it to fit you. So, if everyone, or another person has IoT, then it can … they can personalize it to help them." Katie explored and improved her knowledge of IoT, which ultimately, provided her guidance to allow her to pursue her passion project.

At the conclusion of the camp, semi-structured interviews were held with each of the campers. While discussing the approach to learning STEM that was taken in the camp, Katie indicated that while in the exploration phase, "[she] learned how to actually program … 'cause [she] always did drag-and-drop, and [she] want to program now. At first [she] didn't know any of these tools existed, so [she] learned that these can help you program, and [she] learned about different phrases, like 'syntax' … [she] just learned about a lot of the tech, the programming …" As she explored more, she learned more about the applications of her chosen technology, and started to teach others to use it as well. She gained confidence in her ability to engage with the technology – which is when she shifted into the creation stage of her journey. She reiterated this in the focus group, stating that "I think my knowledge of programming in general improved a lot, because before, even though I liked technology and math and science, I really got an opportunity to physically program with different kits, because it was mostly drag and drop, so not I can take the kit home, I can actually program and I know more about programming now."

5.3 Creation

The final stage of the design process, as utilized for this thesis, is the creation stage. This is when the participants start to implement all that they have learned, to start to create a working (or semi-working) prototype, to help demonstrate the goals of their project. Each of the participants worked through the Understanding and Exploration stages, as they made their way to the Creation stage of the process. Creation included the active actions of coding, circuit making and using tangible objects to create their prototype. Again, because each participant focused on different technologies and approaches to making their prototype, the creation stage looked different for each participant, but it was noted that by the time they were each at this stage, they did take on a leadership role, in some capacity.

5.3.1 Alannah

Alannah worked through the exploration phase rather quickly, possibly because she came to the camp with a pre-conceived idea of what her passion project might look like (see Figure 5.4, above). She knew the end goal of her project, but she needed to explore the different ways that she might be able to get to that point. During the exploration phase, Alannah demonstrated an interest in Micro:bits. In the initial planning of her passion project, she indicated, rather timidly, "I was [thinking] to use the Micro:bit to sense it or something." By the end of Day 4, Alannah knew what she needed to do, and how she was going to do it, in order to create her prototype. In her Day 4 reflection, after being asked to reflect on the following three questions:

1. How do you think your project could work with the Internet of Things? (Example: Could you connect it to other stuff? Could you use the information your project collects?)

2. Where would your project fit into a civilization? What kinds of people could it help?

3. What do you need to finish up tomorrow?

Alannah indicated that she would need to utilize Micro:bits and 3D printing to bring her concept to life. Her response is in figure 5.14.

Figure 5.14
Alannah's Day 4 response

Internet of things are tools and technology that improves and helps us to make our lives much simpler with the help of the internet. The tool that I am using for my project is a micro bit. And, the micro bit is going to send an alarm to the phone through Bluetooth. My project can prevent road accidents. My project prevents people from texting or checking their phone while driving. For tomorrow, I just need to code my micro bit and 3D print my project.

As Alannah learned and grew in her STEM abilities, she became more assertive in her abilities and that really led her in the creation stage. An example of this was when she initially started to plan her prototype. As she was introduced to Micro:bit and 3D printing, she initially wanted to create a device that physically locked the phone into the device as the person drove, but it did not require coding, because the person physically locked the phone into the holder. However, as she explored the technology more and had conversations consulting the leaders, she decided that she would incorporate coding into the device through the use of the Micro:bits and the 3D print would just hold the phone and the sensors required for her device to work. The self-awareness of her abilities and her potential to create to incorporate IoT is a large indicator of a shift in her abilities (see findings on A Self-Perceived Shift in STEM Abilities/Mindset).

Following the creation stage, Alannah completed her project prototype and she was proud of it. She worked alongside one of the camp leaders, to problem-solve and trouble shoot through the coding of the Micro:bit, to bring her concept to life.

Upon completion of her project, Alannah recognized that her creation could become a legitimate product that could be beneficial to those in society. Alannah's confidence in technology use grew throughout the week, and by the end of it, she recognized the *real* impact she might be able to have. During the final research interview, at the end of the final day of camp, Alannah was asked *If you were to have infinite resources, infinite coding knowledge … what would you want to take your project and do with it? How would you want to make it bigger, better, more global … what would you ultimately want to do with it?* Alannah answered with:

> So [a researcher] told me that this actually can happen in real life, so I was thinking that I want to go to an engineer or something like that, and actually put the holder into the car system. You know there's a lot of cupholders, so there'd be cupholders but also a phone holder. And you know how my Micro:bits wires are all out, they would all be implanted into the car so it's a thing in real life.

Alannah worked through the Understanding, Exploration and Creating stages, and ultimately, recognized her own potential.

5.3.2 Simone

As previously mentioned, it took Simone a longer time to get to the creation stage of the process. Simone spent a prolonged amount of time in the exploration stage, which hindered her ability to get to the creation stage. However, once she got to this point, she did engage in creating her prototype, albeit with a lot of guidance and redirecting of her attention by the camp leaders. As previously mentioned, Simone was the only participant from this study who did not actually complete her passion project prototype, but she was okay with that.

The creation phase of Simone's journey was quite unique in that she did end up creating a lot, but her focus was wide spread; she did not focus on one specific technology. Her process could be likened to being a "Jack of all trades, and a master of none." Simone created a lot of 3D prints, bracelets and 3D objects with the 3Doodler. Simone did not create much using the IoT technologies, and when she did, it was because she was guided to by camp leaders, in attempts to help her finish her passion project.

During the final focus group interview, the participants were asked *did you like, or dislike, the way that the camp allowed you to make a passion project?* She responded, saying that "[she] liked it because [they] got to be creative, and [they] got to try all these things that we never got to try before." Simone was effective at creating things; however, her passion project was not a main focus for her.

5.3.3 Katie

Katie progressed through the stages of the design thinking process rather quickly. She had been exposed to technologies and creating using technologies previously, so she worked in the creation stage of the process for a longer amount of time. Field notes from researchers indicate that Katie used very little support from leaders while she worked to create her passion project. She worked independently, and only sought out support when she was really stumped.

By the end of the week, Katie had successfully created her device. She had worked through trouble-shooting and problem solving, as she effectively created the circuitry for her device, as well as the background coding that allowed for her device to alert users when they needed to look away from their screen. Figure 5.15 shows the device, as well as the coding that was required.

Figure 5.15
Katie's completed Passion Project

During the final focus group interview, the participants were asked *throughout the week, we kind of gave you guys choice for what you did -- would you have preferred for us to give you a book that says "do this, do this, do this -- this is your end product* to which Katie responded that

> it would have been a lot less fun, and it gave us a lot more possibilities to learn about trouble shooting and analyzing all the variables that could go wrong. With a book it shows what to do, what should happen, but when we had to make our own

> passion project, we had to think of what we can and can't do, what could go wrong, what might go wrong along the way -- there's more possibilities for learning how to trouble shoot.

Katie took full advantage of the creation stage, implementing the things she had previously learned, while also trouble shooting, and expanding on her exploration stage.

5.4 A Self-Perceived Shift in STEM Abilities/Mindset

Ultimately, the main focus of this research is to discern whether participants can recognize a shift in their perceived STEM abilities, over a week-long camp. While tracking each of the participant's progress through the various stages of the Design Thinking process, it was also critical to consider whether they demonstrated, or explicitly stated, that they recognized growth or enhanced abilities in STEM. It is with this change that it might be possible to connect an experience like this week-long camp, with an improved STEM identity.

At various times of the week, each of the participants demonstrated growth and improved abilities in STEM. From the onset of the study, two of the three participants demonstrated a clear interest in and desire to pursue STEM. Pre-camp surveys were utilized in order to determine a baseline understanding of participants self-perceived abilities in STEM. The third participant answered STEM related questions with vague, rather unclear responses, such as "I don't know," A summary of responses can be found below, in table 5.4

Table 5.4
A summary of STEM related responses for Pre-camp Survey

Participant	What kinds of words would you use to describe your abilities in science?	What kinds of words would you use to describe your abilities in math?	Do you envision yourself pursuing a job in a STEM-focused area (ie. engineer, scientist, mathematician)? What kind of job would you like to do when you're older?
Alannah	I love science and I think I'm pretty good at it.	I also love math. The thing I love about math is that you need to use different equations to solve different problems. And, I love solving problems. I am really good at math.	I want to be a doctor when I grow up. I believe that you need do to work with technology in every profession/job.
Simone	Weird	I don't know	I want to be an art teacher
Katie	I think I would describe my ability as "average" or "decent". I get As in science, but I'm not a perfect student.	I would describe my abilities in math as "great" and "very well" because math is one of my favourite subjects and I do very well in math.	Yes. I really want to be some kind of engineer when I grow up, but I'm still unsure what kind. I really like Robotics since I do it at my school, so I think it is a future for me.

This baseline understanding of how the participants situate their abilities and interests in Mathematics and Science was critical for recognizing a shift.

Throughout the week, the emergence of confidence during the creation stage of the design thinking process was a key indicator of a shift in abilities. Each participant demonstrated a shift in their confidence while using various devices and that was critical in the shift in their abilities that all three reported at the end of the week. With this confidence, was an increased interest in creating with the technologies. During the focus group interview, at the conclusion of the week, participants were asked *do you think you'll use the tech again, once you get home?* to which there was a resounding "yes!" from all participants. This was followed up with *are you excited to?* Which was also answered with an enthusiastic "Yes!" from all participants.

5.4.1 Alannah

Throughout the week, observational notes were taken that all indicate that Alannah maintained a leadership role, while still implementing her plans and creating her passion project. Most notably was Alannah's work with a younger camper, who had little previous exposure to technology creation. This camper had consumed technology, however, using it to create was new to him. When using Micro:bits (the technology that Alannah eventually used to create her prototype), Alannah was very eager to help others. At various points throughout the week, it was noted that Alannah completed her task, then went and assisted the younger camper with his task.

This assumption of the role of a leader aligned with her increased confidence in using the technology. She was willing to help others when they were stuck with Micro:bits, however, if they asked her questions about other technology she was unfamiliar with (such as Arduino), she would redirect them to seek help from a leader. This emphasizes the confidence that she gained through the exploration and creation phases that she worked through.

Alannah's shift in self-perceived abilities in technology were apparent through her actions, but she also explicitly stated. At the conclusion of the week, the participants in the focus group were asked *Do you think that throughout the week, your ability to see yourself as a Scientist, Engineer or Mathematician has shifted?* She replied, stating that

> Since I was little, I wanted to be a doctor, and every profession, it doesn't matter what profession you are, has to work with technology -- so that helped me to actually see where I'm going in the future. It's not only knowing the human body, but the technologies … I really love science and math, but before this week, I used to not like technology at all, because I didn't know how I would handle it and stuff like that, but now I actually know how to code and understand that stuff, so it's fun for me now.

Alannah always knew that she liked science and mathematics, which is seen in her pre-survey responses, however, she admits that she was not so sure about technology but recognized the importance of it.

As a result of interactions that occurred throughout the week, Alannah recognized a shift in her abilities to create with technology. She reiterated her shift, when the focus group was asked *did you like, or dislike, the way that the camp allowed you to make a passion project?* and she responded, saying "I liked it because we got to make our imaginations come true -- I never thought I would make a phone holder, but now after I made it, I actually know I could do it." Alannah recognized that previous to the camp, she could not have envisioned herself creating her prototype, but through the growth that she went through in the camp, she re-envisions herself.

5.4.2 Simone

Throughout the week, Simone became very confident in her abilities with the artistic technologies and that played a large role in how she became a leader. In the final Day focus group interview, when the group was asked *do you think your abilities in science, math or engineering have changed throughout this week?* Simone volunteered that "[she] learned a lot about coding because [she previously] didn't know how to use the littleBits and the 3D printer and the doodler pen, so [she thought she] learned a lot about technology." This learning was echoed in the way that Simone demonstrated proficiency in creating bracelets using the Digiloom, and 3-dimensional objects, using the 3D printer and the 3Doodler, a device that heats up plastic, and extrudes it, similar to a hot glue gun; when extruded, the plastic hardens, which allows the user to create 3D objects. As she became more confident in her abilities, she began showing others in camp how to use these technologies to create. Although the other campers were not utilizing these technologies in their passion projects, when others needed a bit of a break from their focused project, they would ask Simone to show them how to use the various art technologies and Simone gladly took the opportunity to show, teach and share what she had learned. Her confidence was clear through her actions with the art technologies; however, she never took a leadership role while using the IoT technologies.

In the focus group, when participants were asked *do you think that your abilities in Science, Math or Engineering have changed throughout this week?* Simone responded "I think that I've learned a lot about coding because I didn't know how to use littleBits and all of the other stuff that we learned how to use, and the 3D printer and the doodler pen – I didn't know how to use those things. That's why I think I learned about technology and things like that." This question was followed up *with would you consider yourself more well-versed in coding, like do you have more of a knowledge of it?* To which she responded "Yes." The technologies that she mentions are limited when it comes to IoT application. LittleBits have the potential to incorporate IoT concepts, however, at a rudimentary level. The personalization of littleBits is rather limited, as opposed to Micro:bits or Arduino, which require more substantial coding. This limited growth in IoT technologies and coding is clear through her response “a little bit” to the question *do you think that has changed your idea of yourself as a coder?* This was following up by *how?* To which she responded “I used to think coding was really hard and kind of boring, but now I think of it, since I kind of know how to do it, I think of it as fun. It’s not as boring anymore.” When given the choice, she often chose not to interact with the IoT technologies, so it makes sense that she indicates that she now “kind of know[s] how to do it.”

Although her growth in this area did not seem to be extensive, when she was asked *do you think that throughout the week, your ability to see yourself as a Scientist, Engineer or Mathematician has shifted?* she indicated that “I think, I didn’t really know much about it, so I didn’t really think I ever wanted to do that. But now I have more of an open mind about what I can do.” Her response aligns with her previous actions and answers to questions, indicating that she learned about technologies throughout the week, but the vagueness in her answer demonstrates her uncertainty with using it. However, she did also indicate that following the camp, she thought “[she would] learn even more, because since [she got] to take a kit home, [so she would] keep doing it, [and it would] become even more fun.” She demonstrated an uncertainty with the IoT technologies, but that was accompanied with open-mind to continue exploring.

5.4.3 Katie

Throughout the exploration and creation phases, as Katie became more familiar and comfortable with the Arduino, she began to take on more leadership roles, to teach others how to use the Arduino. During the third and fourth day of camp, while the passion projects were well underway, Katie began to really find a place of leadership in the camp. The campers split up into separate rooms, to allow for more space and more directed help from leaders. To expand, the mentors each had an area of expertise; Katie went with the group that was participating in more in-depth coding and circuit boarding. Alongside Katie, there was a young boy (age 6), who took an interest in coding, so he was also in that room. As Katie became more versed in the Arduino, she began to take on the role of a teacher, as she showed the younger camper how to use the Arduino and the different parts. This was the point where her position as a leader became very apparent. By the end of the week, she had completed her own project, and also helped the younger camper learn the basics of Arduino bread boarding and coding.

This increased confidence was accompanied with a shift in her self-perceived abilities in coding and STEM. By the end of the week, Katie's confidence prompted her to go beyond the prototype that she had made. She mentioned that "[she] would probably use [her prototype] in real life, then after a while, take it apart and make other things." Once she left the camp, Katie felt that she could use the technologies that she had learned to make new creations.

At the end of the week, Katie's understanding of STEM profession also had also shifted, which could contribute to a shift in her ability to envision herself as a STEM professional. During the focus group, participants were asked *before the camp we asked* *you to describe scientists or mathematicians, are there any words you would like to switch or include that you maybe didn't think of before the camp?* Katie responded with "I think they're very considerate about the world -- before I just thought they just do it to create, but they think about the world how they can change the world, they're more considerate of other people and how their invention can affect the people." She connects back to the understanding stage of the Design Thinking process. Katie had referred back to helping people often in this process and her final project reflected that, so it is interesting that she now related STEM professionals with that same motivational factor.

Additionally, when Katie was asked about whether she could re-envision herself as a coder, she indicated that same shift, stating that "[her] knowledge of programming in general, improved a lot because before, even though [she] liked technology and math and science, [in this camp, she] really got an opportunity to physically program with different kits, because [before] it was mostly drag-and-drop, so now [she] can take the kit home and actually program -- I know more about programming now … Before this, I actually wanted to be an engineer, but this just kind of makes me want to be an engineer even more, because I get to experience different robots and programming – so experiencing that I now know more about that and I might want to be an engineer one day."

5.5 Summary of Findings

This research aims to understand more about how girls interact with IoT STEM activities, and how the interaction might impact their perceived abilities in STEM. The importance of this is the transfer that could occur into a school setting, or ultimately a career setting. The findings of this research are important for the consideration of people who have a hand in educational reform, teachers included. The findings have been highlighted and organized under the themes that were emergent through data analysis.

5.5.1 Intrinsically Motivating Factors

1. Each participant was driven to engage in the passion project through their motivation to help others.
2. With authentic motivation came authentic engagement in technologies

5.5.2 IoT as a Vehicle to promote Engagement and Confidence

3. An initial interest in STEM was indicative of a greater engagement with IoT technologies.
4. IoT technologies were central to personalized solutions to the problems that the participants aimed to solve.
5. As the participants engaged with the IoT technology more, their confidence in their abilities with that technology increased.
6. A clear goal that implements one IoT technology was correlated with a shorter Understanding and Exploration phase of the design thinking process, which led to a successful completion of their passion project in the Creation phase.

Chapter 6. Discussion

The purpose of this research is to examine some factors that impact girls' self-perceptions of their STEM abilities. Grounded in critical pedagogies, this research is a small piece of a large puzzle that is: What can be done to help address the lack of representation of women in STEM professions by exposing girls to passion-based learning in STEM at earlier ages? Gender is one of the variables that contributes to social systems and oppressive circumstances (Wang et al., 2019). This overall problem is complex and multivariant, so this research aims to contribute to the literature that might be used to drive change in schools, to impact career trajectories for young girls. In turn, this may help to alleviate oppressive conditions for women in STEM. This research is by no means an answer to this problem, instead, an insight into the issue.

The focus of IoT in this research, derives from the unknown impact that it has on learning, because of the emergent nature of this technology. Self-determination theory and self-efficacy theory contextualized how researchers considered the self-perceived abilities of the participants. Each participant's self-perceived abilities while engaging with IoT STEM activities was central to understanding whether they could envision themselves pursuing STEM educations and careers. The ability to envision themselves as individuals who were interested in pursuing STEM is not predictive of their career pursuits, but it might impact their choices moving forward.

This research was guided by the following sub questions, in which the answers helped inform the overarching research question.

1. How might a week-long March Break Camp impact the development of a young girl's identity as it relates to self-perceived abilities in STEM?

2. What impact, if any, does teaching STEM through the use of Internet of Things (IoT) have on a young girl's STEM identity?

6.1 Overview

The findings that were presented in Chapter 5 were rich and can contribute to the discussions that can be had around this case study. Table 6.1 outlines the major themes considered in deductive analysis, in relation to the findings that emerged.

Table 6.1
Major Findings in relation to Major Themes identified in the research

Stage of Design Thinking	Theme	Findings
Understanding - Empathizing - Defining the Problem	Motivation	1. Each participant was driven to conceptualize their passion project through their motivation to help others.
Exploration - Ideate	Engagement	2. With intrinsic motivation came engagement in IoT technologies. 3. Previous experiences with STEM was indicative of a greater engagement with IoT technologies. 4. IoT technologies were central to personalized solutions to the problems that the participants aimed to solve.
Creation - Prototyping - Testing	Confidence	5. As the participants purposefully engaged with their chosen IoT technology, their confidence in their abilities with that technology increased.

The goal of this research was to understand whether a week-long camp can have a positive impact on the STEM identities of three girls. To determine that, it was critical to follow each of their narratives, through the design thinking steps of empathizing, defining a problem, ideation of their solution, prototyping of their solution and testing of their prototype. The design thinking process helped to frame Marcia's Self-Determination Theory, which strongly guided this research. Self Determination Theory postulates that both exploration and commitment are critical when determining one's identity. However, the participants in this research are quite young and still have ample time to explore, so the goal here is not to try to solidify any of their identities. Rather, the goal is to discern the impact on their identities that this camp has had.

In this chapter, the emergent themes as well as the major findings are used to frame the discussion. The discussion for Motivation (6.2), Engagement (6.3) and Confidence (6.4) are broken down to consider the major findings that fall into the respective theme. Each section considers the three case-studies and how the findings for each one overlap, in relation to one another. Ultimately, the strength in the findings comes from the patterns that are found in this discussion. Following the discussion of the main themes, is discussion focused on a Proposed Framework (6.5) to determine how these themes can be implemented, to answer the research questions posed in this thesis.

It is important to note that the findings of this research are not applicable to all contexts, and they are not meant to be. This research is the story of three girls at a week-long camp that focused on changing a small part of their worlds, and the lessons that we learned in that context, with those individuals. Research Limitations (6.6) were considered following the framework. Following that, recommendations for future research foci, to help contribute to the gaps that currently exist at the intersection of IoT and girl's self-perceived STEM abilities, are included in Future Research (6.7).

Finally, the implications of this research in the context of education are considered in Educational Implications (6.8).

6.2 Motivation

Each of the participants was motivated by different factors, and this motivation drove them to pursue the prototyping of their passion projects. Self-Determination Theory (SDT) is a theory that helps with understanding human motivation (Ng et al., 2012). Schwatka et al. (2020) state that:

> Self-Determination Theory (SDT) makes a critical distinction between autonomous and controlled motivation. Autonomous motivation reflects people's voluntary engagement in activities that they can choose willingly (i.e, they are self-determined) and typically that they find interesting, satisfying, or pleasurable … Controlled motivation reflects motivation to engage in activities based on contingencies that guide the individual's behavior. (p. 351)

Various aspects of the SDT were seen in different areas of the participants' engagement (section 6.2.1 and section 6.2.2) throughout the week.

Overall, autonomous motivation (Ryan & Deci, 2020) played a large roll in each girl's experience in the camp. Intrinsic motivation in this research twofold:

- motivation to elicit change in society drove each of the girls to conceptualize their project, which navigated how they interacted with the different IoT technologies
- motivation for the realization of their ideas, increased engagement in IoT technologies

Once the girls worked through the empathizing and understanding phases of the design thinking process, they could move on to the ideation phase, which was driven by engagement with IoT.

6.2.1 Participants were driven to conceptualize their passion project through their intrinsic motivation to help others

There are a few factors that could have contributed to this common theme. Firstly, the focus of the camp was on *Changemakers*. The camp was marketed as an opportunity for campers to "explore emerging technologies [including the Internet of Things (IoT)] to design and prototype an invention that could improve their lives (or the lives of others)!" (Appendix A). The second factor that might drive the participant's desire to help others was mentioned in the Literature Review, which is the social construct that women are responsible for taking on the 'caregiver' role (McLean, & Syed, 2015). Although often taken for granted, social constructs impact our lives, whether we want to acknowledge them or not. However, by addressing these innate foundational components of our society, it might be possible to contribute to a change in these archaic ideologies.

In all three case studies, Alannah, Simone and Katie demonstrated an innate desire to help others through their actions, rationales and choices throughout the week. In their initial reflections, each girl touches on addressing climate change. Climate change is an issue that humanity is facing, more emergently each year (Malla et al., 2022). As such, in addition to the push for STEM, Ontario education stakeholders have seen a push for Climate Change Education (CCE) (The Government of Ontario, 2009). The focus on climate change was likely a result of their formal education settings and the experiences that they had interacting with CCE. Their experiences in school informed their thoughts in the camp and this is indicative of Marcia's Identity Theory (1980).

Alannah's reflections demonstrate her desire to help combat climate change, through the use of IoT and smart technologies. The most poignant statement that she made was when she touched on our responsibility, as stewards of the Earth. Alannah states that "[w]e live on this earth, we should learn, understand and take care of our earth," and "[w]e can make a lot of useful things with [technology] tools that would benefit civilization." Her reflections from the week, as well as the way that she interacted and created with the technology, were indicative of someone whose motivation in learning the technology was her innate desire to contribute to the greater good of humanity. As the campers started to focus more on their passion projects, Alannah's focus became more specified, as she applied the knowledge that she had gained in school, to address the issue of texting and driving. Alannah focused on a specific issue that she saw in society, then determined how she could apply the knowledge she gained throughout the week to help change the issue for the betterment of society. Alannah was driven by societal norms that she deemed unacceptable and she recognized the need for change and in this, she applied critical theory. The need for change pushed her to work through the design process and create a device, grounded in IoT, that would fulfill her desire to help people.

Simone's motivating factor was not quite as explicit as Alannah's. When responding to the pre-camp survey, Simone was not as forthcoming as Alannah -- there were a lot of responses that left researchers questioning "what did she mean?" However, as the week progressed and researchers obtained more data through daily reflections, candid conversations and her final interview, the importance of civilizations and social justice became obvious. Similar to Alannah, Simone did mention the importance of Climate Change. She mentions the importance of reducing pollution and decreasing paper use in schools. Both of these allude to the desire to combat climate change and global warming – issues that are threatening life as we know it on earth. Additionally, she alludes to the impact that Climate Change is having on bee populations around the world. Although she does not explicitly state the importance of saving bees, she states that she would include bees in her civilization, which suggests that she understands that bees are necessary as pollinators for human food.

Simone's motivating factors evolved throughout the week, having focused on combating climate change, then shifting to helping people do gymnastics. This shift in motivating factor might have come as a result of the scale on which her focus sits. Combatting climate change is a global concern and can be daunting to think about, on an individual impact scale. However, helping someone learn to do a back bridge in gymnastics is a more localized concern and that fact alone makes it more approachable to solve. Her shift may have arisen as a result of an ease of effecting change on a smaller scale. Regardless of why she shifted focus, one common thread was Simone's desire to help people, whether it be directly (her gymnastics creation) or indirectly (combatting climate change).

Katie's motivation throughout the week mirrors that of Simone's; her focus shifts, but the motif of helping others remains constant. When Katie was asked about creating a civilization that incorporates things to make sure everyone is happy and healthy, Katie's response, (seen in Figure 5.9) echoed the desires of both Simone and Alannah. Katie touches on a number of factors that impact people's lives in today's society, including healthcare, entertainment and basic living needs. The ideals that Katie outlines, contrast the living conditions of many in today's Canadian society and her response demonstrates her desire to help create living conditions that are conducive to a life devoid of suffering.

Additionally, Katie continually mentions the importance of eco-friendly substitutes for everyday consumption, specifically transportation. Her mention of creating technology "that runs on greenhouse gases" alludes to her desire to lessen greenhouse gasses in our atmosphere. She makes it clear that she is cognizant of humanity's carbon footprint. The way that the environment is being impacted by current practices in our society is damaging for future generations and Katie's desire to change these practices, demonstrates her selfless motives in her civilization creation.

Katie's focus on helping others remains constant throughout the week, but her approach to helping shifts. Katie's passion project implemented technology in a way that allows people to use technology, but safely. She recognizes the importance of technology in 21st century lives, but also that it can have drawbacks. During the day 3 reflection, Katies response, (Figure 5.11), indicates that Katie has observed in her life the impact that technology is having on people. She has recognized the juxtaposition of technology benefits and drawbacks, and she has conceptualized a way that she can combat the drawbacks. In combatting the drawbacks, she creates a way for technology to still be beneficial, without the rejection of the technology altogether.

6.2.2 With intrinsic motivation to learn IoT came ideations of their passion project

In this thesis, motivation played a role in more than one way. Initially, motivation is what drove the participants to determine the goal of their passion project, during the empathize step of the design thinking process (see section 6.2.1). Following that, motivation played a key role in how the participants interacted with the IoT technologies as they defined their passion project -- in the definition step of the design thinking process. For all three of the participants, intrinsic motivation to learn the IoT technology was rooted in realizing their end goal of the passion project. However, not all three girls engaged in inquiry-based learning to the same extent. Alannah and Katie were fully immersed and invested in inquiry-led learning, whereas Simone had a harder time demonstrating problem-solving; a outcome of inquiry-based learning. As outlined but Hughes et al., (2022), inquiry-based learning is

> Rooted in progressive, constructionist, and constructivist pedagogical philosophies, it can be used to solve problems, to answer questions, and to assist students in developing the transferable skills and global competencies that they will need in their academic and professional lives. Inquiry-based learning is always present in problem-based learning and often co-exists with project-based learning. (pp. 21-22)

The process that both Alannah and Katie followed in this exploration is indicative of an inquiry-based approach to learning. Alannah and Katie were clearly engaged in the design process as they shifted from defining the problem to creating ideations of their passion project. At this point, both Alannah and Katie were intrinsically motivated to learn the technology and apply what they had learned in order to problem solve. The girls' progress was characterized by this willingness to problem solve, after they had acquired a base knowledge of their chosen IoT technology.

For the whole duration of the camp, Alannah and Katie were both motivated to bring their passion projects to life, through constructionist learning and application of their chosen IoT technologies. They worked through understanding the problem they wanted to solve, in order to explore the technology that would be most suitable for creating their passion project. Throughout the process, Alannah and Katie remained authentically engaged and invested in learning their chosen technology, because of the outcomes that result from learning it.

During the exploration phase on Day 2 of the camp, Alannah reflected:

> I coded a lot of things using the Micro:bits. For example: smiley face, sad face, watch, heart, name tag and a die. We can make a lot of useful things with these tools that would benefit the civilization. For example, with the help of Micro:bits you can turn the heater down when no one's home. Not only you are saving your money, you are also saving the earth by not using energy for no reason.

She understood the various capabilities of the Micro:bit and took a lot of time exploring it to really understand the application possible for her passion project. All of the different things that she did with the Micro:bits had nothing to do with her project; however, her base knowledge was necessary to apply it in the context that would benefit her project.

Similarly, Katie committed fully to learning an IoT technology with the end goal of creating her passion project. During the exploration phase, Katie really connected with

Arduino and observation notes indicate that she was very self-motivated to learn it, seeking very little guidance. Katie worked through problems independently, through the use of resources such as YouTube and Google. Initially, Katie used the Arduino in a very simplistic way – following steps that were provided in the tutorial book that was provided with the Arduino Startup kit that she used. Katie spent a lot of time using this book, while she gained clarity on how to create circuits with a bread board and then how to code those circuits to implement sensors and output devices. However, as the week progressed, she started to implement the knowledge that the gained, to create the personalized prototype for her passion project.

Alannah and Katie were observed to participate in problem solving through trouble shooting, asking questions and searching out solutions (through things like YouTube). With this engagement and motivation, came a stronger belief in their ability to create prototypes from their conceptualized passion projects. Both of these participants created prototypes that could become real devices, and they were both aware of their acute ability to do so.

Conversely, Simone did not seem to have a clear idea of what she wanted to focus on for her passion project for majority of the week. As previously mentioned, an intrinsic motivation to help others was a pattern in Simone's reflections throughout the week; however, she struggled with applying that to a passion project. A large majority of her time throughout the week was spent exploring technologies that were art related and had limited IoT connections.

This finding is interesting, because she very clearly had a passion for art (which was also indicated in her pre-camp survey), but she did not choose to pursue her passion in art as her passion project. Instead, she chose to pursue another passion -- gymnastics. Simone did, however, work with another camper, so it is possible that she may have felt social pressure to contribute to a project that focused on gymnastics. Regardless, once Simone had determined a passion project and had a clear idea of the end goal, her engagement with IoT technologies became much greater. In her Day 3 reflection, Simone indicated that "IoT is confusing but fun" which might indicate a lack of understanding the foundational skills required for understanding IoT technologies, such as coding. However, in her Day 4 reflection, she states how coding would be implemented in her final project: "The green light means we did something good, the red is for when they do something bad. Those are the coding that we would give the robot." This indicates an increased understanding of the applications of IoT, through sensors and output devices (the lights). Although the shift is seen between learning IoT because she had to, and learning IoT because she wanted to, it was quite late in the week and the extent of it was not as prevalent as the other girls. Simone was not fully engaged in interest driven problem solving, like the other two girls were.

Although Simone's journey looked quite different from that of Alannah and Katie, these findings reflect the importance that intrinsic motivation plays in creating a foundation for purposeful engagement in learning IoT technologies. People are not simple, and we do not just have one passion. However, the motivation to engage with IoT technologies was derived from each participant's end goal of their passion project. The key for this motivation was a clear understanding of what they wanted to create, which then drove them to learn how they could apply their chosen IoT technology to achieve that goal.

Collectively, the three case studies demonstrated the importance of helping others as an intrinsically motivating factor for interactions with the Internet of Things. Their desires to help others, and create equity for all, is indicative of Friere's Critical Pedagogy (Freire, 2005). Explained in the Theoretical Framework, these pedagogies create opportunities for "students [to] gain a critical self-consciousness and social awareness and take appropriate action against oppressive forces" (Mckernan, 2013, p.425). The design of the camp was founded in critical pedagogies so these findings were somewhat expected.

Each of the participants of this research engaged with the technology differently and differed in their approach to solving social issues; however, a common thread was the importance of citizenship as they created. The empathy that the girls demonstrated in the onset of the camp is the first step of the design process, which helped guide the analysis of this research. This empathy that they felt helped them to define the problems that motivated them to engage with IoT throughout the week.

Self-Determination Theory (SDT) aims to determine which motivational factors have an impact on learning and achievement in the classroom. SDT helped to inform the shift from "empathy" and "defining the problem" (first two steps of the design process), to ideating their prototypes (the third step of the design process). In this process, constructionism became central to their processes. Constructionist approaches to learning promote choice and initiation, which facilitate self-determined, or intrinsic motivation (Standage et al., 2006).

As the girls explored their motivational factors, the girl's engagement with IoT shifted from prescriptive, instructor led activities, to activities that were driven by their interest and intrinsic motivation. They began to engage authentically with the technologies, learned more about the capabilities and limitations of the various IoT technologies and began to ideate their creations.

6.3 Engagement

While the participants moved through the design process, the shift from ideating their projects to prototyping their projects was recognized by a commitment to explore the specific IoT technology that they deemed appropriate for prototyping their concept. This deep dive into their chosen technology came as a result of the personalized opportunities that IoT provides (Kortuem et al., 2013). These findings coincide with those of the studies with a focus on IoT in education, which came before it (Kiryakova et al., 2017; Kortuem et al., 2013).

The engagement from each of the participants looked very different and they all had different paths that led them to that part of their journey. However, there were some common themes that arose between the participants that will be explored in this section: an initial interest in STEM was indicative of a greater engagement with IoT technologies and IoT technologies were central to personalized solutions to the problems that the participants aimed to solve through the ideation of their project.

6.3.1 Previous experience with STEM was indicative of a greater engagement with IoT technologies as participants prototyped their projects

The camp was designed to give participants the freedom to engage in the technologies that they felt would be the most effective in creating their passion project. Each of the participants chose to focus on technologies that incorporated coding; both drag and drop (Micro:bit) and programming using a language (Arduino). Alannah and

Katie worked quite quickly through the empathizing and defining phases of the design thinking process, whereas Simone took more time, and needed more exposure to the various technologies, before she committed to a passion project and in turn, explored an IoT technology more thoroughly.

Each of the girls came into the camp with varying level of previous STEM experiences. However, they all indicated that they were not aware of what IoT was at the start of the week, so they all came into the camp at the same baseline understanding of IoT. This is important, because one of the main variables that is considered in this research the impact on STEM identity. All three participants were at the same baseline for understanding at the beginning of the camp and the fact that the participants were all at the same baseline understanding of IoT, contributed to why they were chosen as participants in the case study.

From the start of the camp, with the pre-camp survey, it was clear that Simone was rather timid about the camp. The answers that she provided were vague and made it hard to discern her baseline with STEM experiences. When asked a question about creating something that could help others, Simone responded with "Yes" -- vague and undetailed. Although vague, it does not indicate a lack of STEM experiences, but it could reflect the timidness that Simone felt coming into the camp. It is important to note, that Simone was a social butterfly, with her fellow campers – this timid nature was not expressed in social aspects of the camp -- it was only seen when she interacted with technology. As indicated by Gocmen (2012), timidness or shyness, can derive from personal experiences, so this timid nature that Simone demonstrated with technology could be indicative of a lack of experiences with technology.

During the focus group interview, Simone shed light onto how she felt about technology, specifically coding (which is central to IoT), stating that she "used to think coding was really hard and kind of boring, but now [when she] think[s] of it, since [she] kind of know[s] how to do it, [so she] think[s] of it as fun. It's not as boring anymore." The fact that she found it hard before the camp could be an indicator that she did not have many experiences using it, because after only one week, she had already gained confidence in her abilities to interact with technology.

For the first three days of the camp, Simone was very interested in engaging with the art technologies. When the participants were led through prescriptive activities with the camp leaders, Simone did participate, but to a limited degree. Following the instructor led sessions, campers were given free time to explore the technology of their choice and Simone often chose the 3Doodler (3D object making device) or the Digiloom (bracelet maker); neither of which implement IoT. From the pre-camp survey, she did indicate that she was interested in art and art technologies, so it was not a surprise that she was drawn to those. However, it may also have been because those technologies are also more simplistic. The technologies that Simone often engaged with at the start of the week required no coding or previous knowledge of STEM concepts; there was a very limited learning curve for those technologies. IoT technologies, on the other hand require a knowledge of coding, are much more sophisticated and often there is quite a steep learning curve to become adept at using them. This may be an indication that she was overwhelmed by the IoT technologies, so she chose to interact with the technologies that she felt more comfortable with, which were simpler.

On Day 4, however, Simone paired up with another camper when they connected over their love for gymnastics. This pairing helped Simone to focus on her passion project, and guided her to engage in the IoT technology that she and her partner determined would be the most effective in bringing their concept to life. It was at this point that Simone really started to engage in the IoT technologies (which was coding using Micro:bit). The timeline of Simone's engagement with IoT is interesting, because it was later in the week than both Alannah and Katie. The lack of engagement with IoT technologies that was seen with Simone may be attributed to the fact that Simone had somewhat limited interactions with STEM before the camp. However, as the week progressed, and Simone had more time to interact with the various technologies (IoT and non-IoT) and as she did, she became more confident in her ability to interact with the IoT technologies.

Conversely, the other two girls, were very detailed in their pre-camp survey answers and had very clear ideas about STEM and their STEM abilities from the onset (Table 5.2). Both Alannah and Katie indicated that they thought they could create something with technology, that could contribute to making life easier, stating, respectively, that: "Yes, I believe that I can create something, with technology, that could contribute to a better/easier/more fun life because everything we do know is with the help of technology. Technology impacted on our life so much" and "I think I can because I have tried brainstorming different efficient products at school for products, so I think one day I can really make a product." In both responses, Alannah and Katie indicated that they had previously thought about creating this kind of an object. Alannah and Katie both indicated on the pre-camp survey that they intended to go into STEM professions. This might be an indicator that Alannah and Katie have had more experiences and time spent in the exploration phase of their STEM identity formation (Marcia, 1980). Alannah and Katie were older participants (age 13 and 12, respectively) as opposed to Simone, who was 11. This age gap may have contributed to the lack of experiences that Simone had with STEM before the camp.

Marcia's identity formation theory (1980) is central to this understanding, because it takes into account the opportunities for exploration that individuals have, as they move from identity diffusion, foreclosure and moratorium, into identity achievement. Although the experiences with STEM might not always lead to the ideal outcome (such as pursuing STEM careers), it does provide them with opportunities to explore the concepts and that is not a bad thing. Not all girls are going to be interested in STEM or STEM careers, and that is okay, but some will never know if they never have access to those experiences. In this research, all three of the participants seemed to be interested in continuing to explore and learn IoT (although, at differing levels), as a result of their innate motivation to ideate their passion project.

6.3.2 IoT technologies were central to personalized solutions to the problems that the participants aimed to solve through the ideation of their project

In the context of this thesis, purposeful engagement relates to engaging with the technology for a specific purpose. This concept has roots in critical making, which is derived from critical theory (as mentioned in the Theoretical Framework). The specific purpose for each participant of this study differed, often depending on the motivational forces that pushed them to create their passion projects.

All three participants explored the different IoT technologies that were available to them through the prescribed activities that were led by camp leaders. Following that, they were given the opportunity to explore whichever technologies they were interested in. Alannah and Simone focused on Micro:Bits, whereas Katie focused on Arduino.

As previously mentioned, Alannah came into the camp motivated. She mentioned to researchers in conversation that the idea for her passion project originated from a school project, where she researched and created a poster to encourage people to put their phones away while driving. However, with that being said, her motivation to learn technology was not as transparent from the start. Initially, Alannah was willing and enthusiastic to try the technologies, just for the sake of exploration. As she began brainstorming her passion project and thinking of the different technologies that could be utilized to bring her project to life, she then became more motivated to learn the technologies, specifically Micro:bits. While exploring the different options, Alannah reflected, stating: “Today I learned that you can control Micro:bits and Arduino using your phone. I enjoyed using Micro:bits the most. I really like Arduino but I feel like I understood the Micro:bits more and had fun using it.” Alannah recognized her abilities and what she would enjoy pursuing, which was the intent of creating a passion project.

After exploration of the different options available to her, she timidly indicated: “I was [thinking] to use the Micro:bit to sense it or something.” Alannah demonstrated a knowledge of the capabilities and limitation of Micro:bits, so she took full advantage of the personalized aspects of it and really committed to learning how it could be used to create her project. Alannah recognized how she could implement Micro:bit, stating that while people are driving, the phone will have to be in the phone holder and while they are driving, "every time they try to pick up their phone to check it or text, a beep will go on … an alarm … so it will sense it, and then they'll remember that they're not allowed to pick it up, and will put it back." Alannah implemented the sensing capabilities of the Micro:bit (to sense the phone), as well as the output capabilities to create an alarm.

Similarly, Katie took much of the self-exploratory time to explore the Arduino. From the onset of the camp, as previously mentioned, Katie was very interested in technology and coding. This is interesting because she chose to focus on the most sophisticated coding technology that was offered at the camp. The capabilities of the Micro:bit and the Arduino are quite similar, however, the Arduino uses programming languages, whereas Micro:bit uses more drag-and-drop coding. Katie indicated in the focus group interview that "[she] always did drag-and-drop, and [she] want[ed] to program now. At first [she] didn't know any of these tools existed, so [she] learned that these can help you program, and [she] learned about different phrases, like 'syntax' … " Katie knew that she wanted to focus on learning new programming languages, and to do so, she chose to learn Arduino. The differences between the Micro:bit and Arduino emphasize the importance of wide walls (Resnick et al., 2009b), high ceilings and low floors (Papert, 1980) – the capabilities of these technologies are similar, but entry levels are different, depending on the user's previous experiences and understanding of coding/technology.

Katie indicated an understanding of how the personalized possibilities of IoT were critical in creating her passion project. At the end of the week, Katie indicated that "there's a lot of chances to personalize [IoT] … you can customize it, say, when you get home, what priorities you have … you can personalize it to fit you. So, if everyone … has

IoT, then it can … they can personalize it to help them." Katie did just this as she created her project; she took advantage of the personalized possibilities, in order to create her alarm, to help people limit the damage that can result of looking at a screen too much.

The importance of passion in pursuing IoT learning was effectively conveyed, when Katie said: "I liked [the design of the camp] because it gave us more freedom to follow something we're actually interested and something we're passionate about, both of these assisted in completing the project." Through this statement, it is clear that Katie recognized the importance of the passion in the passion project and that was something that drove her to complete her project.

As previously mentioned, Simone had a more difficult time engaging in the IoT technologies so there is limited evidence that she interacted with it as a result of the personalized possibilities of it. However, when Simone reflected on the goal of her project, she did state: "We were thinking of making a 3D printed hand, and an accordion arm, so it keeps it up, we're testing this on a Barbie doll … The green light means they did something good; the red is for when they do something bad. Those are the coding that we would give the robot." Simone still implemented her passion of art in her project, by creating a 3D printed hand, which was central to her design. To add context, Simone's project was meant to help gymnasts do a back bend, with sensors where the individual's hands and feet should be. The green light would turn on when the hands and feet touch all four sensors, and the red light would turn on in any other case. Simone implements the personalized possibilities of the Micro:bit when she indicates that should would have to code it to show a green light when something is done correctly, and a red light when something is done incorrectly. She recognizes that she would have to use the personalized capabilities of the Micro:bit to implement her goals in her final project.

All three participants recognized the importance of the personalized possibilities of IoT as they moved from the ideation of their projects, into the prototyping and testing phases of their passion project creation. The engagement with IoT technologies was central to the jump from thinking about and creating plans for their projects, to actually prototyping them. It was necessary that the girls knew which IoT technology would help them to be successful in their creation and in order to know which technology would be most effective, they each needed time to engage with it.

6.4 Confidence

In addition to motivational factors and purposeful engagement, is the importance of confidence when participants created and tested their passion projects. Two of the three participants demonstrated an increase in confidence in their abilities while using the IoT technology that they focused on. Self-Efficacy Theory maintains that cognitive engagement is positively correlated with a student's perception of ability (Greene & Miller, 1996). When the participants had confidence in their abilities with the various technologies, they were more willing to push themselves to learn the technology, which promoted cognitive engagement with that technology. The technologies that each participant engaged with differed, so the difficulty of the technology also differed. However, because the perceived ability is self-determined, through understanding their own abilities, the type of technology that they chose to pursue became insignificant. The implementation of the gained confidence with self-perceived abilities will be explored in section 6.4.2.

By the end of the week, each of the participants in this study were successful in their own rights. Alannah was successful at learning and purposefully engaging with Micro:bits, as well as teaching others how to use it and how to personalize it to meet their passion project end goals. Simone was successful at learning Micro:bits, and implementing that into her passion project; however, her leadership skills came out when using the art-based technologies. Katie was successful at problem solving and effectively teaching herself how to code and create circuits with an Arduino, as well as teach younger campers introductory Arduino concepts. Creating additional opportunities for success was important for further developing participant's confidence with the use of technology -- most noticeably, for Simone. As mentioned in section 6.3, people participate in activities where they know that they will be successful (Bandura, 1977) and Simone's lack of participation with IoT technologies indicates a lack of confidence while interacting with these technologies.

6.4.1 As the participants created prototypes with their chosen IoT technology, their confidence in their abilities with that technology increased

Each of the three girls conceptualized, prototyped and presented their final products, which demonstrates confidence in their creations. This confidence was driven by their knowledge in their areas of expertise, in both the IoT technology that they decided to use, as well as the passion that drove their engagement. Two of the three participants began to take on the roles of leaders as their confidence increased and they became more proficient with the IoT technologies. The other participant had factors that impacted her interactions with IoT, so likely did not have enough time to feel proficient enough to grow into a leader that could help other learn the IoT technology that she focused on. However, she did become a leader, teaching other campers about the technologies that she was passionate about -- art-based technologies. The importance of STEAM (as opposed to STEM) is demonstrated in Simone's engagement with the art technologies. Although not a main focus of this research, an additional (but not really surprising) outcome was the way that art technologies emboldened Simone to take on a leadership role. Simone engaged with the art technologies, initially, because she was interested in art. However, as the week progressed, she shifted from a consumer of the tech, to someone who had the confidence to teach others how to use the art technologies.

Alannah, Simone and Katie all engaged with the technology that they knew that they would be successful in; for Simone, that was not always IoT technologies. For all three participants, with success came confidence, and with confidence came an increased self-efficacy while interacting with their chosen technology.

As Alannah's motivation to learn Micro:bits became more clear and focused (for the purpose of creating her passion project), the engagement with the technology shifted from a shallow *engagement for the sake of engagement*, to *engagement for a purpose*, or cognitive engagement (requiring problem solving, troubleshooting etc.). Through an increase in engagement, Alannah started to demonstrate more confidence in her abilities with the new technologies. It is interesting, because during the final focus group interview, she mentioned that "[she] really love[d] science and math but before this week, [she] didn't like technology at all, because [she] didn't know how [she] would handle it, but now [she] think[s] [that she] actually know[s] how to code, so it's fun for [her] now." She began the camp with a lack of interest and confidence in her abilities to engage with technologies, but as the week came to an end, her confidence increased.

6.4.2 An increase in Confidence with IoT technology increases self-efficacy with technology

These case study participants' perceived abilities and self-efficacy in these areas became more recognizable as the week progressed. Self-efficacy, defined as the self-perceived ability to successfully perform a task, plays an important role in the outcome of the task (Lam et al., 2014). In the beginning of the week, all three girls conceptualized civilizations that provided opportunities for everyone to be happy and healthy -- but they did not use the technology to further any of these ideas; they were simply ideas. However, as they became more familiar with the technology and learned both the abilities and the limitations of each technology, they honed in on their passion projects. This shift from Climate Change and other environmental issues, to more specific concerns that they felt they could combat using their knowledge and the technology available to them, was critical in their perceived abilities in STEM. Bandura (1977) outlines this stating that

> people fear and tend to avoid threatening situations they believe exceed their coping skills, whereas they get involved in activities and behave assuredly when they judge themselves capable of handling situations that would otherwise be intimidating. (p. 194)

While making her passion project, Alannah made the decision to pursue the use of Micro:bits, as opposed to Arduino -- a more sophisticated technology that could have created a more specialized project -- but that emphasizes the beauty of IoT. Alannah had the freedom to choose a technology that met her needs, and her confidence in Micro:bit drove her decision to use it to bring her concept to life. Through making this decision, she acknowledged her confidence in her abilities to use Micro:bit.

Her self-perceived ability in STEM (specifically, technology creation) was apparent as the week came to an end. At multiple times in the week, Alannah mentioned that she knew she wanted to work in medicine, even before the camp. However, during the final focus group, she acknowledged that:

> Since I was little, I wanted to be a doctor, and every profession, it doesn't matter what profession you are, has to work with technology -- so that helped me to actually see where I'm going in the future. It's not only knowing the human body, but the technologies … I really love science and math, but before this week, I used to not like technology at all, because I didn't know how I would handle it and stuff like that, but now I actually know how to code and understand that stuff, so it's fun for me now … every profession has to work with technology, so [the camp] actually helped me see where I'm going in my future now -- so knowing about the human body, but also technologies.

Alannah recognizes that her career trajectory/dream job has not changed, but now she has the knowledge, confidence and perspective to recognize the importance of her abilities in technology. During the same focus group, Alannah states that she appreciated the camp because "[campers] got to make [their] imaginations come true." When the researchers followed up and asked Alannah to expand, she says that "I never thought I would make a phone holder, but now after I made this, I actually know that I could make it." Alannah shifted from a girl who "didn't like technology at all" to a girl who used technology to create a prototype of a device that she "actually know[s] that [she] could make." Her perceived ability to use technology, specifically IoT, was impacted (even to a minor amount) through the processes and activities that she engaged in throughout the camp.

Alannah’s confidence in her perceived ability was clearly demonstrated through her response. She demonstrated that if she follows the necessary steps, she could move beyond the prototype that she conceived throughout the week, and ultimately create a product that could change lives; she could harness technology to make life better.

This was solidified by a conversation that she had with a camp leader, which she reflected on, saying: “So [a camp leader] told me that this actually can happen in real life, so I was thinking that I want to go to an engineer or something like that, and actually put the holder into the car system. You know there’s a lot of cupholders, so there’d be cupholders but also be a phone holder. And you know how my Micro:bits wires are all out, they would all be implanted into the car so it’s a thing in a real life.” The conversation that Alannah had with the camp leader had an impact on her and allowed her mind to shift from conceptualizing the idea, to having the confidence to pursue legitimate prototyping.

Similar to Alannah, Katie came into the camp with an interest in aspects of STEM. She indicated, on more than one occasion that she enjoyed engineering, and she was a part of her school’s robotics club. That said, she came into the camp with limited knowledge about IoT. Throughout the week, as Katie interacted more with the technologies and gained an understanding about applications of IoT, specifically, in the context of her passion project, she began to take on a leadership role. When the campers split into separate rooms, Katie was surrounded by other campers who were interested in Arduino and coding, but most were younger and less experienced with coding. Katie started mentoring these campers, and she shared her gained knowledge about Arduino, both coding and circuitry. Katie’s new occupation as a leader in the camp demonstrates the confidence that she developed while working with the Arduino and expanding her abilities while using it.

At the end of the week, during semi-structured interviews, " … when [researchers] said that [the project] could be anything we want, anything we're passionate about, I thought of first technology, because I like technology … my knowledge of programming in general improved a lot because before, even though I like technology and math and science, I really got an opportunity to physically program with the kits, because before it was mostly drag and drop. I know more about programming now." The confidence that Katie demonstrates is apparent in her language used (i.e., "I know more … ", "my knowledge improved …"), but it was also noted in researcher's field notes, that her body language exuded confidence; she was sitting up straight and had an open posture, with an easy relaxed feel about her. Katie exuded confidence in the way she held herself when speaking about her achievements from the week.

This increased confidence was accompanied with a shift in her self-efficacy in coding and STEM. By the end of the week, Katie's confidence prompted her to go beyond the prototype that she had made. She mentioned that "[she] would probably use [her prototype] in real life, then after a while, take it apart and make other things." Once she left the camp, Katie felt that she could use the technologies that she had learned to make new creations and that speaks volumes to the confidence that she has in her abilities to create using Arduino, even without *her* mentors (camp leaders) present. This confidence helped frame a shift in how Katie recognized her abilities.

At the end of the week, during the focus group interview, Katie stated that

> [her] knowledge of programming in general, improved a lot because before, even though [she] liked technology and math and science, [in this camp, she] really got an opportunity to physically program with different kits, because [before] it was mostly drag-and-drop, so now [she] can take the kit home and actually program -- [she] know[s] more about programming now … Before this, [she] actually wanted to be an engineer, but this just kind of makes [her] want to be an engineer even more, because [she] got to experience different robots and programming -- so experiencing that [she] now know[s] more about that and [she] might want to be an engineer one day.

The importance of the engaging authentically with the IoT technology is demonstrated in this statement. Katie had the opportunity to develop her STEM knowledge and she felt even more motivated to pursue engineering, which is indicative of a stronger self-perceived ability in that subject area.

Opposite to the experiences of the other girls, Simone's lack of confidence in IoT likely came as a result of limited interactions with it. Although she had limited engagement with coding and IoT technologies, she did state during the focus group interview, that "[she thought] that [she had] learned a lot about coding because [she] didn't know how to use littleBits and all of the other stuff that [campers] learned how to use, and the 3D printer and the doodler pen – [she] didn't know how to use those things." It is interesting that she chose to mention littleBits, because of the IoT technologies, that was one of the most simplistic. Again, this justifies the importance of wide walls (Resnick et al., 2009b), and high ceilings and low floors (Papert, 1980). There were times throughout the week when Simone engaged in prescribed coding activities so that is likely what she is referring to when she states that she learned about coding. It is also important to note that all of the technologies, with the exception of one, that she listed in her response were not connected to IoT. The question did not specifically ask about IoT, so that might be why she chose not to focus on those technologies, but the fact that she felt that her abilities in Science, Math or Engineering had shifted as a result of the technologies she did interact in-depth with, contradicts the findings that IoT technologies help improve self-efficacy in STEM. Two critical factors that could have impacted Simone's journey to a shifted self-efficacy in STEM were previously explored: her apparent lack of previous STEM experiences, which interfered with her confidence and motivation to engage with the more advanced technologies available to the campers (IoT technologies) and a limited focus on the passion project end goal, which was likely a result of feeling overwhelmed learning a lot of new technology over a short time.

Interestingly though, there was a definite shift in Simone's confidence in technology use and STE(A)M. Simone demonstrated a lot of confidence while using a number of different technologies that implement art. Simone committed a lot of time to learning the different art-based technologies throughout the week. Initially, she was quite content exploring it on her own. Through this engagement, Simone began to participate in similar problem solving and troubleshooting to that of Alannah and Katie. In addition to the confidence that Simone began to exude, through this problem solving and troubleshooting, came her ability to help others problem solve. Simone was seen helping others learn these tools, on a number of occasions and similar to the other two girls, that demonstrates an increased confidence, which likely led to her shift in her self-perceived abilities in STEM. This shift is solidified by the statement she made during the focus group: "I used to think coding was really hard and kind of boring, but now I think of it, since I kind of know how to do it, I think of it as fun. It's not as boring anymore." Simone echoes these findings, when she states that when she thinks of herself as a coder, her perspective has changed "a little bit." The importance of art was really apparent for Simone and that justifies the implementation of a constructionist approach to learning. Simone had an innate desire to create physical, tangible artifacts, that came as a result of her expression through art. That was her "in" to IoT. Once she was comfortable with those technologies, she began to approach IoT technologies.

6.5 A Proposed Framework for Improved Self-Efficacy while using IoT

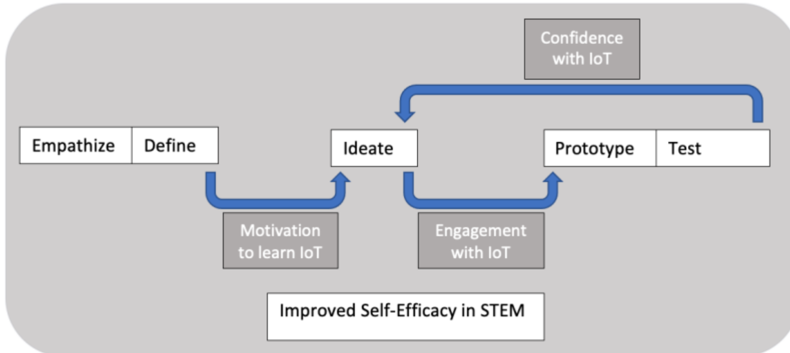
Self-efficacy in STEM for all of the participants followed an observable pattern through the week. Each of the girls worked through the design process, with specific variables driving the movement through the process. The variables were: *motivation* → *engagement* → *confidence* → *self-perceived abilities in STEM*. It was clear that as the participants empathized with others, and defined problems in their lives, they found motivation for learning about IoT through STEM activities. As their motivation pushed them to begin ideating their passion projects, their engagement with their chosen IoT technology increased. As their engagement increased, they began to ideate and test their projects, which demonstrated that their confidence in their abilities also increased. Throughout this process, the participant's self-efficacy in STEM also increased. Although it is shown above in a linear model, the interactions between the different aspects does not always move in a linear formation and as the participants engaged further with the IoT technology, they often came back to the ideation stage, which was mediated by motivation. A key component to this process is reflection.

Each of the participants were prompted to reflect on their processes throughout the week, which created a cyclic process, as they worked through definition of their project, ideation of their project, and creation and testing of their project.

An example of the steps that were taken throughout this process can be seen through Alannah's process. During the prescribed activities, she was willing to learn and explore – her motivation to learn IoT was apparent, albeit rather shallow, as she followed the steps given to her. As she explored and defined her project, her motivation to learn Mirco:bits (the technology she chose to use to bring her passion project to life), was apparent. The exploration of technologies, and reflection on their capabilities and limitations was central to her choice to focus on Micro:bits. As she began to determine the actualization of her passion project, her initial ideas for ideation required refinement and she used feedback to ideate something that she could actually create. As Alannah created a plan for her project, she engaged with Micro:bits in authentic ways, in order to bring her project to life, during the prototyping stage. This is where authentic engagement was apparent. Throughout the process of prototyping, Alannah tested and refined her prototype, which increased her confidence, as she was seen problem solving with limited assistance from camp leaders. Additionally, she began to help others with Micro:bits; another sign of an increased confidence. This increased confidence drove her motivation to ideate additional aspects to add on to her initial prototype. This process was demonstrated to have an impact on self-efficacy in STEM.

Figure 6.1

Proposed Framework for a path to Improved Self-perceived Ability when using IoT



This framework can be used to help track the journeys of both Katie and Simone as well. It is important to note though, that the pathway to improved self-efficacy was different for each of them.

Katie's journey was similar to that of Alannah. She came to camp motivated to learn and engaged in the technology exploration as a result of motivated interest. As she began to define the solution to her identified problem, her motivation to help other evolved into motivation to learn IoT technologies (specifically, Arduino), in order to bring her solution to life. After Katie determined that the Arduino technology was the most effective for her project, she really pushed herself to learn the basics of Arduino. Through this learning, her engagement was purposeful and focused on her end goal, which resulted in the ideation of her project. As Katie began to prototype and test her project, it was clear that her confidence in her abilities was visibly increasing, as Katie began to take on a role of leadership, through teaching a younger camper how to use the Arduino. Similar to Alannah, Katie's self-efficacy in STEM improved as a result of this process. Unlike Alannah, Katie did not seem to loop back to the motivation component, likely because she was so focused on her end goal throughout her process and that motivation was enough to drive her to her finished product. She worked through problems, as she looped back to the ideation phase of the process, but she was not motivated to add additional aspects to her prototype. This could be contributed to the fact that Arduino is a more sophisticated technology, and as such, it may have been too time consuming to make the project more complex.

Simone's journey with IoT technologies was quite different from the other girls' journeys. Although Simone came into the camp with an enthusiasm to learn, her journey through motivation, engagement and confidence, which impacted her self-perceived ability in STEM had very little impact by the implementation of IoT. She was not as motivated to explore the different technologies, unless they were steeped in art, and that emphasizes the importance of STEAM, as opposed to STEM. From the beginning, she indicated that she was interest in art technologies, and that was proven to be true time and time again throughout the week.

Unlike the other girls, Simone's journey started in the engagement stage. Simone seemed to need time to explore and engage with the technology before she felt motivated to learn more about IoT or pursue her passion project. Once she engaged with the various technologies, she began to demonstrate a motivation to learn and understand them more, but they still were not IoT technologies. Only after she explored the more simplistic technologies, did she start to really focus on her passion project, determine her goal and engage in learning the IoT technology that would help her achieve this goal. It was interesting that she decided to pursue a project that focused on anything other than art, but as previously mentioned, that could have been because of social factors (section 6.2.2).

As Simone worked on her passion project, she was enthusiastic about helping other learn a gymnastics technique, which drove her motivation and thus, purposeful engagement while learning the IoT technology -- Micro:bit. However, as previously mentioned, the lack of time that she spent engaging and creating with the Micro:bit likely led to a lack of confidence in her ability to create with IoT.

A positive outcome of her lack of focus on the coding technologies, was the time that Simone took to engage with the art technologies. Simone was self-motivated to learn the art technologies because of her passion for art. As Simone learned these technologies, she engaged purposefully, as she began problem solving and troubleshooting when things went wrong with them. In this case, Simone was not creating for a purpose, like the other girls were -- she was creating for the sake of learning the technologies and following her passion, and given the setting (a camp), that was okay. She lingered in the 'defining the problem' stage of the design process for much longer than the other girls. There was a definite disconnect between her initial motivation to explore IoT (which was to help others) and her actions to learn those technologies, however, the implications of previous STEM experiences (section 6.3.1) and her lack of focus on the end goal of her passion project were key factors in this. So, although Simone was not as impacted by the IoT technologies, there are other factors that need to be considered when implementing IoT technologies, in hopes of shifting one's self-perceived STEM identity. In an alternative setting (like a school), students often have a task that they are seeking to complete and there is much less opportunity for free exploration (beyond the primary division), but this finding might reinforce the importance of free exploration beyond the primary division. More on this in section 6.8 on educational implications. Although Simone's motivation was not connected to her passion project, it was connected to a passion. As she engaged with the art technologies more, her confidence increased and, just like the other girls, she started teaching others how to create with those technologies.

At the end of the 5-day camp, each girl indicated that she could they could see themselves implementing the knowledge that they gained during their experiences in the camp. Each girl's self-efficacy while using these IoT technologies, and thus, in STEM, improved. Katie indicated that "[she] know[s] more about programming now," Alannah said that "[she] never thought [she] would make a phone holder, but now after [she] made this, [she] actually know[s] that [she] could make it," and Simone stated that "[she] didn't really know much about it, so [she] didn't really think [she] ever wanted to [work as a scientist, mathematician or engineer], but now [she] ha[s] more of an open mind about what [she] could do." Although each of the girls took different paths to reach this point, it is important to note the role that time and authentic learning experiences, which were driven by passion, played on their STEM identities.

Although the difference in paths taken for each of the girls is important and significant in its own right, there was a commonality of iterative processing between the girls journeys. Each of the girls went through the steps at different rates and at different times, but every one of them participated in a cyclic process, which consisted of creating, then cycling back to either motivation or engagement. At no point did any of the participants stop learning, or moving through the framework. The importance of reflecting can be seen in this iterative movement through the framework. This aspect of the framework mirrors that of the design process.

6.6 Research Limitations

Although the findings of this research indicate that there was an impact on each of the participants, the overall impact on identity is not simple to discern. The nature of this research is to study humans, and as such, it is expected that the experiences that contribute to each of the factors (motivation, engagement, confidence and overall, self-efficacy) is non-linear and looks different for each individual. STEM identities grounded in social contexts and are based on one's ability to recognize themselves as a member of STEM groups (Kim et al., 2018). The formation of a social identity is multi-variant (Kim et al., 2018), so it is not as cut and dry as a quantitative study might be; the study of a plant's growth, while considering the independent variable of exposure to sun demonstrates an observable and clear correlation between the variables. This research is not that simple. There were a number of variables acting simultaneously, as the girls interacted with STEM through IoT, so it was critical that key indicators or motivation, engagement and confidence were clear and straightforward.

As a result of the complex nature of studying people, there are other factors that were not considered in this research and therefore, create opportunities for Future Research Recommendations. The limitations of this research are outlined below:

- Methodological Research Design (6.6.1)
- Participant Pool (6.6.2)
- Camp Recruitment (6.6.3)

6.6.1 Methodological Research Design

The majority of the limitations within this thesis arise as a result of the methodological approach to addressing the research questions posed. This research implements a case study approach. The decision to implement a case study approach is emphasized by Merriam's (1988) statement that case study research is "selected for its very uniqueness, for what it can reveal about a phenomenon, knowledge we would not otherwise have access to" (p. 33). However, in order for a study to be considered a case study, there must be clear boundaries; the case must be intrinsically bounded (Merriam, 1988). Within these boundaries lies some of the limitations of this thesis.

The findings, including patterns and correlations between variables, that were determined in this research can only be applied to the context of this research: the data were collected over a week, in an immersive camp that focused on IoT technologies, for three girls who were between the ages of 10 and 13. The insight that was gained can only be applied to a setting of this nature. As a result of this, it is unknown if this research can be transferred to other contexts, where the environment, pedagogical approaches, age of participants, or other settings where the motivation is not passion (such as a prescribed activity that might be given in school).

The nature of educational research is that it is often pilot projects and short-term interventions (such as this). When identity is considered, short term interventions do not gain the kind of insight that a longitudinal study might. Identity is fluid and different experiences have different impacts on identity (Marcia, 1980), so in a short amount of time, such as a week, it is difficult to really identify the impact that intervention might have. Although the boundaries of this research create limitations for the application of the knowledge gained, it also creates opportunity for future research, as outlined in Future Research Considerations.

6.6.2 Participant Pool

In addition to the limitation of application of findings in other contexts, there are also limitations that come as a result of the choice to focus on three cases. Merriam (1988) defines the 'case' in case study as "a thing, a single entity, a unit around which there are boundaries … a person, such as a student, a teacher, a principal" (p. 27). The cases in this study are the three girls, aged 10-13. The narratives, and therefore outcomes, explained in the discussion of this thesis are limited to that of these three girls. Although this was a deliberate choice for this specific research (see Methodology), it does create an inability to generalize the findings for all girls who participate in IoT as they explore STEM concepts.

6.6.3 Camp Recruitment

One final limitation of this research was the way the camp was advertised. The poster that was used to recruit participants for the camp can be seen in appendix A. The camp was advertised as a technology camp that:

> will explore emerging technologies [including the Internet of Things (IoT)] to design and prototype an invention that could improve their lives (or the lives of others)! Students will have access to a variety of technologies to help them complete their projects, including 3D printing, circuit-building (paper, fabric, or other), coding, and more!

With that in mind, it can be safely assumed that the individuals who were targeted by this advertising had a pre-established interest in technology and, likely, STEM. The targeted audience creates a bias and therefore, limitations to this research.

6.7 Recommendations for Future Research

The nature of qualitative, ethnographic research is to understand people; it "enables study of behaviours, norms, beliefs, customs, values, applied human patterns and human phenomena as these are expressed in practice" (Shagrir, 2016, p. 9). Although this research is complex, in that complexity lies the beauty of it. To gain any kind of insight into people and their identities, it is important to have studies such as this, as well as future studies that can build off the outcomes of this research. The recommendations that I put forward for future research all have implications within the methodology of this research.

It is important that this kind of research, specifically the framework developed in this thesis, be tested in alternate settings. Setting alterations could include the types of IoT technologies that are made available to participants, as well as the specific context for the learning. This research was conducted in a week, in a camp setting where the participants were recruited through the interest in technology and STEM. Future research may implement the recruitment of participants, where the camp outcome was not made obvious through advertisements. It would be interesting to see whether the individuals who choose to participate in a camp within those parameters have a pre-established interests in STEM and if not, whether they were able to follow the same framework that was established in this thesis. A camp such as this would be more indicative of a classroom setting, where students come into learning with various interests, skills and abilities.

Although this research focused on girls, with the end goal of learning about how a camp setting such as this, can impact self-efficacy and ultimately, STEM identity, it would be interesting to see whether boys are impacted similarly to girls.

In addition to shifting the focus of the 'case' in the case study, the boundaries of the case study could also be considered in future studies. The settings of this research allowed participants to be flexible in their learning and exploration of IoT. Participants were given the freedom to deep dive into learning any of the technologies that were made available to them, in their attempts to create artifacts that solved a problem that was important to them. Future research might implement an alternate setting, where the flexibility for creating is limited. Similar to how the alternative participant pool would be more indicative of a classroom setting, this alteration in the research methodology would be more reflective of a classroom. As will be discussed in Implications in Education, teachers are required to teach and assess students on particular curriculum expectations, so free exploration is not always a viable approach to learning in a classroom setting. It would be interesting to determine whether the framework that was developed in this thesis could be applied to a setting that does not allow for students to pursue their passion as they learn about STEM.

6.8 Implications for Education

Girls who have a pre-established interest in technology need to nurture that interest and that emphasizes the importance of the "passion" in the passion project. In the contexts of education, this research contributes to the importance of students having the opportunity to learn through their passions. Although this research was done in an alternative setting that differs from the prescribed nature of a classroom, there are lesson learned that can be implemented in the classroom.

Education in Canada, specifically Ontario, is a public entity and as such, learning outcomes are prescribed by the government. Teachers are required to implement the learning of a curriculum for each subject area. There are specific learning outcomes that teachers are required to assess, which often makes it hard for educators to plan lessons that allow for students to learn through the lens of a passion. However, pedagogical approaches to learning that allow for passion to shine, include those mentioned in the Theoretical Framework. The lessons learned in this thesis emphasizes the importance of maker pedagogies, which implement the ideologies of constructionism, critical theory and self-determination theory.

With the pursuance of passion, implies the importance of choice for students. In the context of this camp, participants had the choice to pursue whichever technology they felt helped them achieve their goals for the week. With that, they were intrinsically motivated and “deep learning will follow if students are engaged and intrinsically motivated, and that curricular connections will be identified based on their choices, rather than selected by the teacher” (Hughes & Morrison, 2021, p. 106). Their intrinsic motivation drove the participants to learn the technology and ultimately, led to an improved self-efficacy with that technology. The improved self-efficacy with their chosen technology bled into an improved self-efficacy with technology (and therefore, STEM), in general.

One of the most prominent findings in this research is the impact that art had on Simone, as she engaged with technologies. This finding emphasizes the need for different pathways “into” the curriculum. In the literature, STEM is a main focus of education, however, these findings make a strong argument for incorporating the Arts into STEM; STEAM. Not all students are going to love science and technology or math (both main curriculum subjects in Ontario schools), but in the case that they do not love these subjects, art might be used as a pathway for students to ‘buy in’ to these subject areas.

The findings of this research contribute to the body of work that emphasizes the importance of these inquiry-based pedagogies in education. With that, is the importance of teacher professional development that helps evolve pedagogies, which allow for passion to play a role in exploration for students. Teachers need to be equipped with knowledge, theory and experience in order to create classroom environments that allow for students to pursue their passions, while also learning specific concepts.

Although it was not a major focus of this research, findings also indicate the importance of the use of IoT for social justice education. Through the planning and implementation of the technologies, all three participants had a focus that was centered around helping others. As previously mentioned, this could have been an implication of the focus of the camp being “Changemakers” – see Research Limitations. However, the focus on helping others demonstrates another access point for teaching girls STEM, specifically in these contexts, through the use of IoT. Again, this creates an emphasis for incorporating the “A” into STEM – however, through this lens, the “A” would be for more than just visual arts. In this context, the “A” would extend to incorporate the humanities. Ultimately, this form of STEAM would be an interdisciplinary approach to education, creating entry points for learning through a number of avenues.

Chapter 7. Conclusion

As society shifts further into a technology and innovation centralized foundations, the need for individuals who are educated in STEM disciplines is essential. In learning STEM through the implementation of inquiry pedagogies, authors have argued that students also learn global competencies that are necessary for success in the 2022 workforce (Hughes & Thompson, 2022). The Council of Ministers of Education, Canada (CMEC), outlines global competencies as “overarching sets of attitudes, skills, and knowledge that can be interdependent, interdisciplinary, and leveraged in a variety of situations both locally and globally” (CMEC, n.d., para. 5). It is important that both boys and girls developing these skills, and in turn, contribute to society in STEM professions. However, as it stands, there is a large discrepancy in the number of women who pursue and maintain careers within the STEM fields of society.

This research does not aim to determine ways that the pipeline of women in STEM can be increased, rather, it offers a glimpse into factors that may impact a young girl’s identity and where STEM can be situated within that identity. To guide this research, the main research question was “How do the perceived STEM identities shift for three girls, aged 10-13, from beginning to end of the Changemakers March Break Camp?” Two sub-questions were used to help focus the research:

- How might a week-long, immersive camp experience, focusing on inquiry-based making, impact the development of a young girl’s identity as it relates to self-perceived abilities in STEM?
- What, if any, impact does teaching STEM through the use of the Internet of Things (IoT) have on a young girl’s STEM identity?

To address these research questions, an ethnographic, case study methodology was implemented. The implementation of this methodology was grounded in a number of theoretical approaches to learning and identity development.

Identity status theory (Marcia, 1980) indicates that identity is fluid and different experiences and interactions inform identity. This research is informed by the four identity profiles (Table 3.1) that have been outlined by Marcia in his Identity Status Theory. In cohesion with identity formation, is Critical Theory, which is founded in Paulo Freire's beliefs that oppressed individuals hit barriers to self-fulfillment. Self-fulfillment has roots in identity, so both aspects of human life must be considering while trying to understand how girls can develop STEM identities. In developing these identities and addressing barriers that limit girls from pursuing STEM in their academic and professional futures, self-efficacy must also be considered, to contextualize how girls feel about their abilities in STEM. As such, Self-Efficacy Theory guided this research, as I tried to understand how an individual's self-perceived abilities to be successful in an activity, are demonstrated by how they interact with the activity.

In addition to these theories, the approach to learning throughout the camp had foundations in Constructionism and Self-Determination Theory. Both of these theories position the learner at the center of learning. Constructionism dictates how the learner learns (construction of objects that are meaningful to them), whereas SDT helps to understand why the learner learns (motivational factors that "facilitate or undermine intrinsic motivation, autonomous extrinsic motivation, and psychological wellness" [Ryan & Deci, 2000, p. 1]).

Findings are guided by the Design thinking process, which can be seen in figure 5.1 of the Methodology section. The findings of this research are multivariant and complex, but through the analysis of data and implementation of thematic coding, information can be organized into key findings that fall into key thematic ideas.

Motivation is a large factor that can impact the learning of STEM through IoT. It was found that the research participants were intrinsically motivated to help others, and that motivation drove the participants to conceptualize their passion projects. This was the starting point for participants, as they dove into learning STEM through IoT. Once motivated to conceptualize their project, participants began to engage with the IoT technologies. Their intrinsic motivation to help other drove the participants to learn the IoT technologies. Findings also indicated that a greater initial engagement with IoT was indicative of having previous experiences with STEM. The participants did not necessarily have previous experience with IoT, rather, STEM activities that introduced them to the skills and ideologies that STEM learning promotes.

The engagement of participants also came as a result of participants having the freedom and flexibility to learn IoT through personalized solutions to problems that were important to them. An example of this was the choice between two different technologies that did similar things; one was more simplistic while the other was more intricate. One participant chose the simplistic option, while another chose the more complex option; these decisions were made based on how the technology could help them achieve their goal of the passion project.

Finally, following engagement, came confidence. While tracing participant engagement, it became obvious that confidence increased as the participants engaged, in a purposeful way, with the technologies. That is to say that as they authentically created with the IoT technologies to help them create the artifact that they had envisioned, their confidence in using the technologies increased. As the participant's confidence in the technologies increased, so did their self-efficacy in technology. Beyond the participant's self-efficacy with their chosen technology, was their increased self-efficacy with technology, in general. The confidence that they had gained transferred to other technologies, and that had major impacts on participant's self-efficacy.

In attempts to visualize these findings, a proposed framework was created with foundations in the design process. Motivation was connected to understanding (empathy and define); engagement was connected to exploration (ideate) and confidence was connected to creation (prototype and test). This proposed framework is intended to be a guide to help future research in understanding these concepts in alternate contexts. The proposed framework can be seen in figure 6.1 of the Discussion section.

Research limitations were largely influenced by the methodology that was implemented in this research. The limitations of the research arise as a result of the boundaries that encapsulated the case study:

- the context of data collection – time frames, focus of learning, flexibility that prompted participants to follow their passion
- the inability to generalize beyond the narratives of the three participants
- the way in which participants were recruited from advertisements that were geared toward technology inclined people

These limitations help to inform the recommendations for future research which includes studies that apply the proposed framework in other contexts, the recruitment of participants in a way that limits the pre-study bias of interest, and finally, whether the framework can be applied to experiences for boys. Research in these areas is critical for better understanding how learning and engaging with IoT can contribute to STEM identities.

In addition to recommendations for future research, I have provided ways in which this research and the findings can be implemented in an educational context. This research highlights the importance of maker pedagogies, passion-based learning and the interdisciplinary approach of STEAM education vs. STEM education. Beyond the implications within an educational context, there can be recommendations made for other education stakeholders, namely parents and teachers.

Although the impact of parents or guardians was not a main focus of this research, the impact that they have on forming a child's identity is immense (Aleni Sestito & Sica, 2014; Macfarlane, 2022). With that in mind, parents can introduce their children to IoT and STEM activities early on, whether that be at home, or by signing them up for camps or clubs, such as the one conducted in this research. Through increased early exposure to STEM and IoT, girls have a chance to nurture STEM identities earlier in life and that might impact their future STEM trajectory.

This research emphasizes the importance of inquiry-based learning, which in turn, emphasizes the importance of teacher professional development that teaches best practices for inquiry-based pedagogies. Specifically, this research implements constructionist learning, through the use of IoT and passion-based learning. All of this can be encompassed within a Maker pedagogy. As outlined by Hughes and Dobos (2022)

> Maker pedagogies build on inquiry-based practices, such as project and problem-based learning (PBL), design thinking and the kinds of remixing practices often highlighted in media literacy programmes. Based on our research, we extend our own definition and understanding of PBL to include passion-based learning, which focuses on student driven interests and inquiries that position students as agents of change in their communities. (p. 3-4)

Through accessible and informed professional development, it might be possible for teachers to implement maker pedagogies, to foster the early development of STEM identities for girls.

Increasing the pipeline of women in STEM is a monster issue within our society, that cannot be simply answered within one research study. However, the insights gained in this research might prompt teachers, parents and educational stakeholders to alter how they teach young girls about STEM. If girls are exposed at earlier ages through the use of IoT and Makerspace learning, it is my hope that they might be more likely to pursue careers in STEM. This could be a factor that contributes to balancing out the number of women in STEM professions, so they can be seen, heard and respected.

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Appendices

Appendix A – Changemakers March Break Camp Advertisement

Appendix B - Digital Design Journals: Reflection Prompts

Monday March 11, 2019: Reflections

• If you were able to design your own civilization, what would you include?

• What kinds of things would be needed so that everyone could be healthy and happy?

• What kinds of technology would it include?

Tuesday March 12, 2019: Let's Make Change!

Today, we talked about some problems that could be solved with our "Internet of Things" inventions – like using too much electricity and monitoring gardens to feed people without enough food. What other problems can you think of that we might be able to solve through our inventions? These can be problems that happen at your school (bullying), or bigger problems in the world (people living in unsafe areas). Why are these issues important to you?

Tuesday March 12, 2019: Reflections

• What did you discover about the Internet of Things (IoT) today?

• What tools did you most enjoy using?

• What kinds of things could we make with these tools that would benefit the civilizations we talked about yesterday?

Wednesday March 13, 2019: Reflections

• Why did you choose your project and/or goal for the week?

• How do you think your creation could help improve other people's lives? Or improve a civilization?

• Do you think the Internet of Things (IoT) is a good thing or a bad thing? Why?

• What are your "next steps" for your invention? Are there any other maker tools that would help?

Thursday March 14, 2019: Reflections

• How do you think your project could work with the Internet of Things? (Example: Could you connect it to other stuff? Could you use the information your project collects?)

• Where would your project fit into a civilization? What kinds of people could it help?

• What do you need to finish up tomorrow?

Appendix C - Letter of Information & Consent Forms

ChangeMakers March Break Camp 2019
Request for Consent:

Our faculty is committed to engaging in ongoing research related to education. To that end, we are asking for both your consent and that of your child to participate in research connected to the activities in this March Break Camp. With the approval of the UOIT Research Ethics Board (REB #15-094), our goal is to evaluate the impact of production pedagogies (described below) and emerging technologies such as the Internet of Things (IoT) on students' perceptions of and involvement with civic engagement and social justice. Participation in the research component of this camp is entirely optional and students will not be penalized in any way if they do not participate.

Production pedagogies are student-centred approaches to teaching and learning, drawing on constructivism, constructionism, project- and problem-based learning to create an environment in which important questions, big-picture projects, and *making* drive the learning process. In contrast to the 'transmission' model of the traditional classroom (emphasizing a unidirectional flow of knowledge from teacher to student), makerspaces enable students -- or 'makers' -- to construct knowledge by working on projects and creating with physical and digital tools.

In these spaces, civic engagement and social justice can be explored through *critical making*. Beyond simply creating objects for the sake of doing so, critical making emphasizes the exploration and critique of social phenomena through the process of creating tangible or virtual artifacts, enabling students to draw their own conclusions through their engagement with multiple media.

Data will be collected from students at various times during the week. All activities will be a part of the regular camp program; however, only data collected from students who have consent from parents/guardians and who have consented themselves to participate in the research study will be used in the analysis and reporting of findings.

Participation in this research would involve the following commitments for your child:

1. **Presurveys:** At the beginning of camp, participants will be asked to complete a brief online questionnaire, which should take no longer than 15-20 minutes to complete. Questions will be related to their past experiences with making, digital technologies, as well as their perceptions of and experiences with civic engagement and social justice.

2. **Focus groups or open-ended interviews:** In small focus groups of 3-4 students or one-on-one informal interviews, participants will be asked to reflect on their experiences and learning during the camp.

3. In addition to using the above as data in our study, the research team will observe camp activities and interactions and collect data using observation notes, audio recordings, and video recordings of selected session proceedings. These recordings will be transcribed and students will be assigned a pseudonym; they will <u>not</u> be identified by name or using any other identifiable information. Copies of digital texts (videos, infographics, participant journals/reflections) and tangible products (3D printing, littleBits/Arduino projects, other constructed items) will also be collected as data and anonymized.

There are limited risks to participating in this study. However, we have outlined below the potential risks for yours and your child's consideration:

- First, there are some physical risks. Participants will be working with electrical components and other craft materials. They may also be standing or sitting for extended periods of time. To mitigate these risks, we will show the participants how to safely use all equipment (providing additional safety equipment where necessary) and will integrate physical activity breaks into the camp's schedule to ease sitting or standing for extended periods.

- Second, there are some psychological risks, such as participants being embarrassed or anxious if their digital/tangible products do not work or if they are not aesthetically pleasing. To mitigate this, we will ensure the participants understand that they have a right to pass and to not share their work if they do not wish to.

Please understand that this is a voluntary project aimed at improving students' academic achievement and skills. Your decision to allow your child to participate or not participate in this research has no effect on their ability to participate in any part of the program, nor will they be penalized in any way if they do not have consent to participate.

Your child may withdraw from the research without penalty, prejudice, or explanation at any time by informing one of the investigators, or by closing the survey on their browser (during the presurvey). The information your child provides will be accessible to the research team only. Pseudonyms will be assigned to each participant once the data has been collected and any images or video where participants are visible will be altered to obscure faces. Further, any names that are present on participant work will be removed before publication.

Data collected from interviews, questionnaires, and student work will be stored securely at UOIT under the lead researcher's supervision. Hard copies of transcripts will be kept in locked filing cabinets in the researchers' offices. We may engage in secondary use of data, which means we may use the information originally collected for this study in other ways (i.e., in other research/data analysis/publications). By consenting to participate, the participant does not waive any normal legal rights or recourse.

Dissemination of research results will be through standard academic means such as journal articles, conference presentations, and books. No participants will be identified by name.

Your signature and your child's signature on the following consent form indicates that you and they have read this letter together, understand/discussed its contents, and agree to participation in this research project. Any questions or concerns about the research can be directed to Dr. Janette Hughes (janette.hughes@uoit.ca; 905-721-8668, ext. 2875). You may also contact the Ethics and Compliance Officer (compliance@uoit.ca; 905-721-8668, ext. 3693).

Thank you for your voluntary participation this important research initiative.

Sincerely,
Dr. Janette Hughes
Professor and Canada Research Chair, Technology & Pedagogy
UOIT Faculty of Education

ChangeMakers March Break Camp 2019
Parent/Guardian & Student Consent to Participate in Research

Participant Concerns and Reporting:
If you or your child have any questions concerning the research or experience any discomfort related to the study, please contact the lead researcher (Dr. Janette Hughes) at 905-721-8668, ext. 2875 or janette.hughes@uoit.ca.

Any questions regarding your rights as a participant, complaints, or adverse events may be directed to the Research Ethics Board through the Ethics and Compliance Officer (compliance@uoit.ca; 905-721-8668, ext. 3693).

This study has been approved by the UOIT Research Ethics Board (REB #15-094).

Parent/Guardian & Student Consent:
By checking the boxes and signing below, my child and I indicate that we understand the risks, benefits, and procedures of this study and give consent for my child's participation. We understand that participation is voluntary and that my child is free to withdraw at any time without consequence. We also understand that my child's data will be kept confidential until such time as the ID key is destroyed, and that my child's data will then become anonymous and part of a larger set of data analysis for scholarly purposes, including but not limited to the creation of research articles and conference presentations. Finally, we understand that neither I nor my child is waiving any legal rights by signing this form.

	Parent/ Guardian	Student
I give consent for the results from the presurvey to be used anonymously in the research project.	☐	☐
I give consent for the results from any interviews to be used anonymously in the research project.	☐	☐
I give consent for the use of any (anonymized) photos, videos, or observations for the purpose of the research project.	☐	☐
I give consent for the use of any (anonymized) physical or digital artifacts created at camp for the purpose of the research project.	☐	☐

Parent/Guardian Name: ***(block capitals)***	
Parent/Guardian Signature:	
Date:	
Parent/Guardian Email Address:	

Student Name: ***(block capitals)***	
Student Signature:	
Date:	

Appendix D – Week Schedule

March Break Camp 2019					
	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
8:00 - 9:00	*Before-camp care*	*Before-camp care*	*Before-camp care*	*Before-camp care*	*Before-camp care*
9:00 - 9:30	Pre-surveys + Community-building activity	Community-building activity	Community-building activity	Community-building activity	Community-building activity
9:30 - 10:00	Intro to Civilizations ("Anno's Magic Seeds") w/ Charting Activity	Intro to **Internet of Things** e.g., *Vector bot*	Intro to Citizenship / Social Justice	Collaboration / Perseverance theme?	Connection of AI w/ IoT
10:00 - 10:15	**- BREAK -**	**- BREAK -**	**- BREAK -**	**- BREAK -**	**- BREAK -**
10:15 - 12:00	Cont'd Civilizations Discussions, Patterning App Community-building Game	Intro to IoT, main activity (-> 10:30) Intro to lab's maker tools (-> 12:00)	Planning + Main project work time	T-Shirt Design? (intro Cricut, have students design?)	Finalizing projects / **Exit interviews**
12:00 - 1:00	**- LUNCH -**	**- LUNCH -**	**- LUNCH -**	**- LUNCH -**	**- LUNCH -**
1:00 - 2:15	Cont'd Civilizations ("Weslandia")	Rotating lab tool sessions cont'd	Main project work time	Main project work time	Finalizing projects / **Exit interviews**
2:15 - 2:30	**- BREAK -**	**- BREAK -**	**- BREAK -**	**- BREAK -**	**- BREAK -**
2:30 - 3:00	IoT maker book: Planning, tool reflection, etc. [1]	Planning, reflection	Planning, reflection	Planning, reflection	Sharing / gallery walk
3:00 - 4:00	*After-camp care*	*After-camp care*	*After-camp care*	*After-camp care*	*After-camp care*

Appendix E – Pre-Study Questionnaire

This research was a subset of a larger study which had an different focus. To accommodate for both, questions that were not used in this specific study were given. To ensure survey fatigue did not alter the results, two versions were given. The order of questions in each version differed, to ensure unbiased results.

Version A

1. What is your full name?

2. How old are you?

3. How do you describe yourself?

__ Female __ Male __ Prefer not to say __ Other: _________________________

4. How often do you use technology at home?

__ Never __ Occasionally __ Sometimes __ Often __ Everyday

5. What kind of technology do you enjoy using?

6. What is your favourite school subject? Why?

7. What does a scientist or mathematician look like, to you?

8. Do you feel a difference in ability when surrounded by kids or students of another gender, versus a setting where it's only your gender? Please explain.

9. Have you had a female teach you STEM education? How many times (roughly)?

10. Do you envision yourself pursuing a job in a STEM-focused area (i.e., engineer, scientist, mathematician)? What kind of job would you like to do when you're older?

11. Who has had the greatest impact on your choice for a career path? Why do you think that?

12. Do you feel like boys are better than girls at science? Technology? Computing? Math?

13. What kinds of words would you use to describe your abilities in science?

14. What kinds of words would you use to describe your abilities in math?

15. Have you ever heard of the "Internet of Things"? Or "Smart" homes/devices?

__ Yes __ No __ Maybe

a. What do you know about it? What do you think it means?

16. Do you believe you could use IoT to make your life better/easier/more exciting? Why/why not?

17. Do you believe you can create something with technology that could contribute to a better/easier/more fun life? Why/why not?

18. Do you believe you can create something with technology that could contribute to a better / easier life for someone else? Why/why not?

19. Have you ever heard of the terms "social justice" or "global citizenship"?

__ Yes __ No __ Maybe

a. What do you think these terms might mean?

20. Have you ever done or created something to improve someone else's life, either on your own or in school?

__ Yes __ No __ Maybe

a. If "yes", what did you do or create?

Version B

1. What is your full name?

2. How old are you?

3. How do you describe yourself?

__ Female __ Male __ Prefer not to say __ Other: _________________________

4. How often do you use technology at home?

__ Never __ Occasionally __ Sometimes __ Often __ Everyday

5. What kind of technology do you enjoy using?

6. Have you ever heard of the “Internet of Things”? Or “Smart” homes/devices?

__ Yes __ No __ Maybe

    a. What do you know about it? What do you think it means?

7. Do you believe you could use IoT to make your life better/easier/more exciting? Why/why not?

8. Do you believe you can create something with technology that could contribute to a better/easier/more fun life? Why/why not?

9. Do you believe you can create something with technology that could contribute to a better/easier life for someone else? Why/why not?

10.Have you ever heard of the terms “social justice” or “global citizenship”?

__ Yes __ No __ Maybe

a. What do you think these terms might mean?

11.Have you ever done or created something to improve someone else's life, either on your own or in school?

__ Yes __ No __ Maybe

a. If "yes", what did you do or create?

12. What is your favourite school subject? Why?

13. What does a scientist or mathematician look like, to you?

14. Do you feel a difference in ability when surrounded by kids or students of another gender, versus a setting where it's only your gender? Please explain.

15. Have you had a female teach you STEM education? How many times (roughly)?

16. Do you envision yourself pursuing a job in a STEM-focused area (i.e., engineer, scientist, mathematician)? What kind of job would you like to do when you're older?

17. Who has had the greatest impact on your choice for a career path? Why do you think that?

18. Do you feel like boys are better than girls at science? Technology? Computing? Math?

19. What kinds of words would you use to describe your abilities in science?

20. What kinds of words would you use to describe your abilities in math?

Appendix F - Post-Study Interview Questions

1. Could you state your first name and age for me?

2. What kinds of things did you learn about this week?

3. What does “social justice” mean to you?

Follow-up prompt: What does it mean to be a ChangeMaker?

Elaboration prompts: Do you think social justice is important? Why / why not?

4. What is your understanding of the Internet of Things (IoT)?

Elaboration prompts: Where might you see it being used? What do you think about it? Why do you think that?

5. Do you think that IoT could be used to help other people?

Elaboration prompt: How / why not?

6. What motivated you to choose your project this week?

7. If you were to keep working on your project, what kinds of things would you want to add to it?

Elaboration prompt: Could anything from IoT help you?

8. Do you have anything else you’d like to add about your experience with the tools or ideas this week?

Appendix G - Post-Study Focus Group Questions

1. When creating a project what were you thinking of when you decided what your goal was for your project?
   - So, what did your end goal end up being?
   - Do you think that your passion was combined with social justice and helping others?
2. Were you doing it thinking of yourself, or what were you thinking of when that was what you decided to do?
3. Do you guys think that your abilities in Science, Math or Engineering have changed throughout this week?
   - Would you consider yourself more well-versed in Coding? Do you have more knowledge of it?
   - Do you think that's changed your idea of yourself as a coder? How?
4. At the beginning of the week, we asked you to use some words to describe Scientists or mathematicians, are there any words you'd like to switch or maybe include, that you didn't think of before the camp?
5. Throughout the week, we gave you guys a choice for what you did. Would you have preferred we gave you a book that says "do this, do this, do this, this is your end project …"?
6. Did you like or dislike the way that it was organized?
7. Do you think that throughout the week, the ability to see yourself as a Scientist, Engineer or Mathematician has shifted? Think back to the beginning of the week, do you think you could see yourself going into Science, technology, engineering or math, or are you still like "I don't know"?
8. Did you already see yourself going into STEM at the beginning of the week?
9. Explain how your project has an aspect of your personality in it.
10. Do you think you'll use your own invention, if it becomes a real-life thing, past the prototype?
11. Does anyone want to add anything else, about their project, or about science, technology, engineering or math?
12. Did you guys do more or less than you thought you'd do this week?
13. What did you expect to do this week?
14. Do any of you think you might use the tech that you take home, after?

15. Are you excited to?

Appendix H - Follow-Up Communications/Virtual Interview Questions

1. What do you remember about the March Break camp last year?
2. Did you notice any shifts in your STEM ability following the camp?
3. Why did you choose to partake in Changemakers last year?
4. What are some words that you would use to describe your identity?
5. How did you determine which words to use to describe your identity? What aspects of your life influenced you?
6. How would you identify yourself when it comes to STEM?
7. Do you plan to take any STEM related programs at college or university?
8. In what career do you envision yourself working when you graduate? What appeals to you about this career?
9. What are you passionate about? What kind of activities do you participate in to express your passions?
10. In your life, what factors or experiences have had the greatest impact on your passions?
11. While at the camp, did you feel motivated to learn more about STEM? Why or why not?
12. Statistics on earned bachelor's degrees in 2012 show that women were awarded 59 % of degrees in the biological/biomedical sciences but in math-intensive fields made up only 43 % of degrees in mathematics and statistics, 18 % of degrees in

computer and information sciences, 19 % of degrees in engineering, and 38 % of degrees in the physical and technological sciences. Do these numbers surprise you? Why or why not?

Appendix I - TCPS 2: CORE Certificate

PANEL ON
RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Laura Dobos

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

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