# AN INQUIRY INTO THE JOURNEY OF THREE CANADIAN WOMEN IN PHYSICS AND STEM

**LISA SUNG-AE COLE**

**Supervisor: Dr. Steve Alsop**

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## Abstract

The under representation of women in the fields of Physics and STEM (Science, Technology, Engineering and Mathematics) was investigated through a semi-autobiographical approach. This study follows the reflection of one educator and the narratives of two former female students who have chosen to pursue post-secondary studies in STEM. The narratives reveal that personal experiences influences an educator's professional practice and these practices can shape a student's classroom experience that may influence the development of a student's interests and possible future outcomes in pursuing a STEM career. Students reveal that real world examples, experiences with hands on learning, collaborative group learning, and connecting to STEM professionals and visiting facilities helped to inspire their own educational journey.

## Acknowledgements

I would like to acknowledge the ongoing support from my family. My lifelong partner and friend, Jason who reminds me of what is important in our life journey together and my two children, Hanna and Reuben, who inspires my curiosity.

Thank you Dr. Steve Alsop for the mentorship and guidance. Our conversations continue to push my own thinking about education and reminds me that different perspectives and ways of thinking are critical for educational change.

Though this study only included two of my former students, I would like to thank all the students I have had the privilege to "teach". Our experiences together have helped me to discover my own purpose and continues to inform my professional career.

Thank you to all the educators I have encountered along my journey – the educators that provided me with mentorship, hope and opportunities for learning in my childhood and adolescence, the educators who inspired my love for physics and STEM in adulthood and the educators I work with professionally. Each of you have contributed to my own learning and continues to shape my thinking. I am inspired by the collective passion and dedication of educators across Canada and around the world.

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# Introduction

Physics Education still faces many challenges today. There continues to be an under representation of women in the fields of Physics and STEM (Science, Technology, Engineering & Mathematics) despite a long history of awareness and extensive studies in science education research. This forms the focus of this study. In what follows I reflect on my personal experiences, my professional journey as an educator and the experiences of my former female students. My approach is semi-autobiographical, combining reflections on my journey with physics and as a physics educator and combining these with reflections of two of my former female students, drawn from a series of conversations. I adopt this approach because my own narrative helps to situate me as the teacher in the classroom. We often think of teachers as trained professionals and forget that teachers are people with human experiences. These life experiences sets the stage for a story and also impacts the ways in which we engage with their students. The actors (teacher and students) of this story are connected, not in isolation from each other, but interweaved together and creates a complex narrative with many subplots. Within the complexity of the story, there must be some common truths and characteristics that can be learned. Two students discuss their experiences within my classroom and how it informs their present and potentially their future. The interplay between teacher and student is being explored this in study to potentially identify and understand strategies that will help to encourage more girls to pursue Physics and STEM in Canada, I start with some details about myself.

## Lisa Cole the physics teacher

I am a physics and mathematics teacher with fourteen years of classroom experience. I have had the privilege of teaching many students over the years and have learned a lot about myself as an educator, and what it means to teach through the work I do every day. I have come to realize that my own experiences – personal, educational and professional have changed the ways in which I think about teaching and how I approach my role as an educator. The narratives I would like to share in this study looks at my own narrative as an educator alongside the narratives of two former female students who have decided to pursue STEM careers.

The interdisciplinary breadth of STEM education often requires teachers to have a strong ability in science, technology and mathematics in addition to skills in technology. However, it is important to note that simply knowing the content areas is likely insufficient for a STEM teacher. STEM teachers must have a robust grasp of teaching and learning through inquiry and a familiarity in the engineering design process. A STEM teacher should provide a learning environment that is grounded in constructivism where the learning experience is student-centered (Sanders, 2009). STEM initiatives in education requires teacher training and professional development that addresses content knowledge, development of technical skills and professional learning to support the development of fluency in a wide variety of pedagogical practices in order to facilitate students in a dynamic learning environment. Students in a STEM classroom should be encouraged to construct their own understanding of concepts as they learn to apply their knowledge into new contexts with the support of teacher mentors. Problem based learning strategies can be used to develop programs that interweaves a rich learning experience for students. As I reflect on my own journey as an educator, I have learned the importance of balancing the delivery of content with the development of skills. I have become a teacher who believes and practices constructivism but also appreciates that teaching is a complex process where teachers engage with their students in a dynamic way to respond and make decisions in the moment that best reflects the needs of the students. I also recognize that my perception of what unfolds in the classroom is flawed at times and I must be willing to listen to students and obtain feedback in order to best support students.

I increasingly recognise that my own philosophies of teaching emerged out of the experiences I have encountered. My personal past has impacted how I view my role as an educator. I am a first generation immigrant who came to Canada with my parents with minimal resources. I could not speak English when I started school. I had a difficult childhood growing up with an abusive alcoholic father and later an abusive stepfather. When I reflect on the role that school played for me I realize it was a place of opportunity, a safe place to go when home was not, and a place that offered me role models that enabled me to imagine a different life for myself. I often think about the people who have helped to shape me into who I am today – I include both positive and negative role models in this discussion. I know that my experiences with my father and my stepfather have made me strong and resilient. I have a mother who has shown strength in preserving the difficult life choices that she has had to make and endure throughout her life. I have learned that life is not always about absolute choices with a definite right and wrong but a series of choices in the moment that has impact on what will come. I have learned to use these life lessons not only in my own personal life but how I approach teaching. I know the difficulties I have faced have made me resilient and perceptive. My relationship with my mother has been a difficult one and I continue to have mixed emotions even in my adult life but this too has shaped me to recognize the importance of women and strong women role models for youth. My personal experiences provide for me a context to some of the issues that our youth may also face and I know these experiences have helped to make me become the kind of educator that I am today. I have been fortunate to have encountered many influential educators in my childhood and my adolescent life. The educators that have opened up opportunities for discovery and exploration provided enrichment opportunities when my family could not afford it. Teachers who cared enough to listen and support me when I needed it and to give me a safe place to nurture my own curiosities and challenge provided me with new directions. These experiences shape what follows as I discover my own professional teaching identity. My personal life helps me to think about the students I meet as people who arrive with personal experiences that shapes the story that will unfold in the classroom. My personal experiences remind me of the importance of creating a safe space for learning for all students. The influential educators I have had, helps me to think about what kind of educator I would like to be and as I learn to teach, I start by modelling what I know.

I find it difficult to talk about contemporary school-based science education without mention of STEM. STEM Education is becoming increasingly popular in Ontario. Although it varies greatly, it often works to educate students in the four subjects in an interdisciplinary and applied approach that connects to real-world applications (Horn, 2014). STEM careers it is argued are becoming more important in today's global economy resulting in rapid growth in STEM fields. According to Canadian Business, Canada's best jobs in 2016 include electronics engineer, occupational therapist, nurse practitioner, scientific research manager, heath and community services manager, aerospace engineer, specialized engineer, petroleum and chemical engineer, oil and gas drilling supervisor, telecommunications manager, engineering manager, software engineer, construction manager, flight engineer and pilot, pharmacist, urban planner and mining, and forestry manager (Canadian Business, 2016). In order to meet demands of this changing job market, countries such as the United States have devoted substantial investments to improve teaching and learning in STEM subjects for both teachers and students. In 2015, President Obama allocated $170 million to create programs such as the National STEM Master Teacher Corps, STEM Teacher Pathways and the STEM Innovation Networks programs. Through these programs, the Obama Administration planned on improving STEM teaching and learning by identifying and implementing programs that facilitates effective instructional practices nationwide which promotes hands-on learning to increase student engagement, interest and achievement (Science, Technology, Engineering and Math: Education for Global Leadership, 2010). In 2015, the United States Department of Education worked in partnership with the American Institutes for Research (AIR) to collaborate with invited experts and thought leaders in STEM teaching and learning to share ideas and make recommendations for the future of STEM Education. The collaboration resulted in a report, *STEM 2026: A Vision for Innovation in STEM Education* within which recommendations for the future of STEM Education are outlined. Recommendations include:

1. Engaged and networked communities of practice.
2. Accessible learning activities that invite intentional play and risk.
3. Educational experiences that include interdisciplinary approaches to solving "grand challenges". Grand challenges are identified as problems that are not yet solved at the local community, national or global levels.
4. Flexible and inclusive learning spaces.
5. Innovative and accessible measures of learning.
6. Societal and cultural images and environments that promote diversity and opportunity. (Tanenbaum, 2016, p. 6)

Science, Technology, Engineering and Mathematics Education is not new. The National Science Foundation (NSF) had programs called "SMET" (Science, Mathematics, Engineering and Technology) in the 1990's, which was later revised to STEM (Sanders, 2009). However, the development and implementation of STEM education initiatives and the support for STEM teachers is still under development with a wide variety of interpretations. Sanders (2009) argues the acronym is ambiguous and the confusion around STEM programming comes from the disconnected approach to teaching and learning in the four separate subject areas. They suggest a better interpretation called, "Integrative STEM Education" (p.21). Integrative STEM Education would include "purposeful design and inquiry" (p.21) that combines technological design with scientific inquiry. Sanders envisions a program that ultimately engages students to solve problems situated in context to real world applications.

I have worked with schools in Ontario that have started to engage in discussions around STEM Education and many have started to implement programs. An increasing number of STEM resources are being developed for classrooms. However, a clear definition, in the form of regional or provincial plan for implementation and a mission for STEM Education is still missing. In some places, the addition of the "A" to represent the Arts where STEM becomes STEAM has taken place. For many STEM/STEAM Education is to be the "new methodology or philosophy" that will transform and revolutionize the current state of education, then it would be appropriate for STEM/STEAM Education to address gender diversity in physics and STEM/STEAM careers. I have recently been extensively involved in imagining what a STEM Education Plan would include and created a system plan for a school board in Ontario (Appendix IV). In the implementation of this plan, long term goals have been set to not only increase interest in STEM subjects but to also critically look at diversity within these subjects. The plan included both content focus but also instructional practices and methodology. Interest in increasing the diversity in careers such as Engineering and Physics continues to be a focus for many professional organizations and post-secondary institutions. The need to address gender diversity comes from a variety of arguments. Hazari et. al. (2007), for example, mentions that heterogeneity in perspectives lead to progress and that a more diverse representation engaged in physics would further capture the interest of the general public. Women make up fifty percent of the world population and when fifty percent of the world population are at a disadvantage in opportunities in physics and STEM, it continues to create a divide – economically, socially and politically (Hazari et. al., 2007). In my own physics classroom, there were more boys than girls. However, over the course of fourteen years in the classroom, the number of physics students increased as well as the proportion of girls in the physics program – once I even had 50% girls in grade 12 physics. I have been curious to investigate these observations.

Outreach programs continue to be developed by organizations to inspire minority groups. However, the results today still indicate struggles in capturing sustainable interest in certain STEM fields and STEM careers. For example, girls interested in STEM careers and STEM disciplines of study are still alarmingly low in areas such as computer science, engineering and physics despite outreach programs. In the United Kingdom, only 20 percent of students who take physics A-level are female and when program requirements for physical sciences and engineering require A-level physics, this automatically restricts the number of women who pursue STEM careers (Davis, 2015 April 22). In the United States, the percentages of women in engineering-related fields are 10.98% for Professional Engineering, 12.18% for Engineering Technicians, and 2.91% for Mechanics and Electronics. (Su and Rounds, 2015). Canada has similar issues in recruiting women in STEM fields. Organizations such as the Ontario Network of Women in Engineering (ONWiE) have investigated the current trends in Ontario. According to 2009 Ontario high school data, 52 percent of all students taking grade 10 science were girls. However, only 40 percent of all students taking grade 11 physics are girls and even smaller, only 33 percent of all students enrolled in grade 12 physics are girls. In 2012, 8000 women were potentially prepared to pursue a degree in engineering in Ontario. Statistics indicated that out of the total number of 7800 first year engineering students registered in Ontario, only 1500 were women. This means only 19 percent of this total enrollment were women and 82 percent were men (Wells, 2015).

I am a STEM educator with a degree in physics. During my undergraduate degree, I was often one of very few women in my physics classes. However, I didn't start my undergraduate degree in physics. I started as an anatomy and physiology major intending to pursue studies in medicine. My family wanted me to purse medicine so that I could be helpful to society and make money. As a high school student, this seemed quite appropriate – I was good in math and science. My journey through undergraduate studies involved many changes – switching from anatomy and physiology to computer science, then ultimately switching to physics. I took many chemistry and mathematics courses and also dabbled in art classes. I was periodically academically lost with no clear focus. During a project course, I started to merge some of my former interests in biology with physics and developed a project working with a doctor at the Montreal Neurological Institute. For the first time, I saw that all the courses I took could be merged together in an interesting application. I worked on a project helping with a medical device called Transcranial Magnetic Stimulation. We worked to develop theoretical models of electromagnetic fields and data visualization to optimize the function of the device. I was interested in pursuing graduate studies at that time but really could not financially afford to do so. I know this experience has played a large role in framing how I teach. Providing opportunities for students to discover how concepts, skills and ideas merge together, and how these ideas can be used to solve problems in the real world. Why are we waiting for students to finish their degree before they discover the power of what they are learning?

I believe that creative, innovative solutions to tough problems such as climate change, fresh water shortage, nanotechnology and cancer comes from collaborative discussions involving diverse perspectives. Diversity provides opportunities to discover new possibilities. I have listened to women who have pursued STEM careers today tell stories about their own journey in order to help inspire and support future women in STEM. Heidi Olinger is the author of *The STEM of Fashion Design*. She is an advocate for girls in STEAM and created a non-profit organization called Pretty Brainy which provides learning experiences that value how girls experience the world. Olinger suggests that educators must understand what girls' value and appeal to those values academically. She suggests that parents must encourage girls in STEM and help to convince them they are capable of accomplishing their goals in order to build up their confidence. Olinger talks about the importance of girls needing to feel like they belong and should be provided with opportunities to meet and be mentored by women role models in STEM. The learning environment must feel safe to take risks and make mistakes. She states, "Let's have girls see the common notions of perfect. They are just that… common… and arbitrary… and that experimentation and prototyping and do overs are the new standard for which to strive" (Olinger, 2014 June 11).

Many women who pursued STEM studies and STEM careers have stories that involve perseverance, development of relationships with role models and a need to "help" or have a purpose. Hanson (1996) explained that "Gender is not just a direct influence, but rather it might also work indirectly through family experiences that affect school experiences and that ultimately affect individual characteristics and experiences" (As cited in P. VanLeuvan, 2004; p. 248). VanLeuvan (2004) writes that boys are twice as likely as girls to prefer a STEM career by eighth grade and into high school. Girls in high school often underestimate their abilities in science and mathematics which results in lower self-esteem and confidence. Societal stereotypes also play a role in influencing adolescent girls (VanLeuvan, 2004). Rong Su and James Rounds state their study indicates that interests are critical predictors of an individual's selection of pursuing a STEM career (Su & Rounds, 2015). They describe two interest dimensions – realistic interests and social interests. Realistic interests involve working with things and gadgets while social interests involve working with people and helping people. According to their results, women indicate stronger interests in the social domain, in comparison to men. Overall, some STEM fields are perceived to be higher in things-oriented careers and low in people-oriented careers. For this reason, the study shows that women tend to select STEM careers that are perceived to be more people-oriented such as Medical science and Social sciences. (Su & Rounds, 2015) Su and Rounds also make a case to suggest interest in quantitative-related activities early in a students' development plays a critical role in determining interest in STEM fields. From the inter-personal perspective, students may "select out" of some STEM fields for not having mathematical ability. (Su & Rounds, 2015) I would argue that STEM careers in areas such as engineering, computer science and physics related fields are also people-oriented careers. Unfortunately, there are stereotypes associated with some of these professions which plays a role in who may choose to enter these professions. Students are only aware of the careers they encounter. Professions such as doctors and nurses are people who we have encountered in our everyday lives so it seems natural to be able to relate to these professions. Other professions such as the medical physicist, computer scientist, data scientist and engineer who may also work in the hospital are hidden professions and more difficult to recognize as possible STEM careers. Helping students discover these hidden opportunities and making connections that all STEM careers are “helpful professions to society” may be necessary to change the perception that is hindering this change. In an article by Susan Wismer (1998), she outlines eighteen tips to be used as a guide to help recruit and support girls and young women in STEM fields. Wismer (1998) suggests the following:

1. Use gender-sensitive language that helps girls and young women to relate to STEM professions.
2. Use gender-inclusive images that illustrates girls and young women as active learners engaged in activities.
3. Demystify science and technology so that science and technology becomes a part of everyday experience. Science and technology is connected to many areas of interest such as music, journalism, politics, philosophy, art and communications.
4. Use a personal touch so that girls and young women exploring the possibilities of STEM can build relationships with role models to support and guide them.
5. Provide programming that uses collaborative approaches to learning to encourage discussion and planning.
6. Emphasize both process and product. Assess both process and product and provide opportunities to demonstrate creativity by valuing the aesthetics of the product.
7. Include some same sex activities as girls will often feel more comfortable leading and taking risks in same sex groups.
8. Use female role models in STEM.
9. Experiential, hands-on learning is important for everyone but for girls it is particularly important because their previous exposure may be minimal.
10. Take a multidisciplinary approach. Make connections between design and technology, science, society and the environment, literature and mathematics to put learning in context.
11. Allow adequate time for activities. Students learning through an integrated approach will need more time to process the problem, plan and develop a product. Time also allows for mistakes and revisions to process.
12. Students improve their academic achievement when students are required to communicate and collaborate. It is important for girls to take on leadership roles during the group learning process.
13. Give positive feedback often.
14. Encourage competent conversation to ensure that students develop terminology. This helps to build student confidence.
15. Debrief after activities or testing to ensure that students don’t personalize and internalize failure. Students must feel comfortable with making mistakes and learning from them.
16. Don’t do things for the girls. Empower the girls to learn to do things for themselves. Provide support and time.
17. No put-downs allowed! Intervene directly and strongly in situations to ensure t this message is clear. A safe classroom space is critical in order to build the relationships necessary for learning.

18. Involve parents and other teachers.  Girls who are supported and encouraged through their parents, teachers and other adults in their lives are more likely to develop interest in STEM careers

(Wismer, 1998 January 1, p. 2-5)

According to Su and Rounds, the gender gap can be addressed by highlighting the societal relevance of STEM knowledge, skills, and careers and their value in improving people's lives.   Working with students and parents to provide relevant information on the importance of STEM fields in our society and the role of mathematics and science is also suggested (Su & Rounds, 2015).  Media has a large influence.  Messaging is important!  STEM professions have large scale impact on our society and our environment and therefore, are deeply connected to our society and has the potential to make the world a better place.  If students are not seeing this connection, it is critical for educators to help students make this connection.  More effort must be made in how we market physics and STEM in a manner that reaches a wider audience.  As a classroom teacher, I have learned to recognize that how I deliver lessons represents not only the intent of the learning but also creates a message that represents the subject I teach.  I have recognized that messaging is critical and highlighting aspects of the subject in ways that might entice a wider audience help students to relate to the subject and makes the learning relevant for a diverse group of learners.

Studies on reducing the gender gap in physics and STEM education have existed for many years.  Physics Education Research (PER) provides insights on how to support learning in physics classrooms with the use of instructional tools such as peer instruction, interactive engagement and cooperative group problem solving. (Lorenzo, Crouch, & Mazur, 2006). Laura McCullough is a physics educator at the University of Wisconsin-Stout and she writes:

> "Physics teachers play an important role in our students' continuing involvement in physics. This is something we need to be especially aware of for our young women because of the continuing underrepresentation of women at almost every level. An awareness of gender issues in the physics classroom and a few simple actions on the teacher's part can do a lot to make the physics classroom a place for promoting women's participation, not hindering it." (McCullough, 2007, p. 317)

Much physics education research has focused primarily on instructional practices to provide students with a conceptual understanding of physics concepts and to develop skills in problem solving and critical thinking. Research has focused on the studying and developing of tools for the cognitive processes behind student learning and for students to develop deep understanding of science concepts. However, the *affective domain* of student learning in physics education is equally important. Student feelings, attitudes, emotions and values have a large impact on a students' ability to learn and develop effective learning behaviours. McConnell and van Der Hoeven Kraft (2011) discuss the importance of the affective domain and student learning in the geosciences. The affective domain includes student motivation and has been demonstrated to have a significant influence on student learning. Students learn better in environments where they feel a sense of "control" for their own learning. McConnell and van Der Hoeven Kraft (2011, p. 72) states, "Students who are able to have some control over their learning experiences (autonomy), who feel capable of succeeding in a task (competence), and who feel part of a classroom community (relatedness), are more likely to be intrinsically motivated to learn within that classroom." When I reflect on my own experiences as a student, the most memorable experiences were in classrooms where teachers created a community for learning that allowed us to explore and question ideas together.  I remember teachers who helped me to discover the magic of science and mathematics and provided me with opportunities to learn through experiences which I would not have had access to at home.  I recall one moment in particular as a key turning point in my future career planning.  I encountered one remarkable teacher in the Department of Physics who provided me with support when I needed it the most.  Edith Engelberg began teaching in the Department of Physics at McGill University in 1959.  Engelberg has been a senior demonstrator for undergraduate physics laboratories at McGill University for over 40 years.  Engelberg once said,

> I love working with young people.  I feel I can make a real contribution to this department and to students….I've only had students who've had problems themselves, and I try to be understanding under those circumstances. It was never easy to be young, and it never will be (As cited in McGillReporter, 2000, Volume 33 Number 6).

I recall entering her office during her office hours just like it was yesterday.  Edith Engelberg was always encouraging and provided support to all her students.  The first time I entered her office was when I was taking the introductory physics laboratory course.  The conversation was quite short and we only discussed the outcomes of the laboratory report which was being returned to me.  However, she did leave me with the impression that her door would be open for conversation at any time.  This was very important to me at the time because I really didn't have anyone else to talk to about my academic future.  My family really didn't know what I was doing.  In fact, they felt that I made a very bad decision in pursuing studies in physics.  I do recall being told once that majoring in physics as a woman might mean that I would never find someone to marry because men don't want to marry women who are smarter than they are.  Three years later I found myself visiting Edith Engelberg's office. Our conversations were invaluable and they helped me to envision my future and to become the person I am today. With very little time left before the application deadline, I decided to apply to the Faculty of Education to become a physics teacher. To be honest, I didn't really know if I would be suitable for a teaching career as I had no experience with "teaching". The only truth I knew was that research not only didn't feel quite right for me but also I couldn't afford to continue my studies. I enjoyed my conversations with Edith and as she described her own educational journey and the work she does, I thought I might be interested in teaching. When I informed my family of this decision, they were "relieved". They felt that teaching is a noble profession that is highly suitable for women. I was once told that teaching would be most appropriate for me as it would allow me to have time with my children when I get married. Apparently, marriage was a possibility again now that I have decided to become a teacher. I grew up in an environment with defined gender roles.

As I entered into the teaching profession, I often reflected on my personal experiences and how those experiences shaped who I am today. As I think about my personal obstacles and how I have learned to manage them, I know that it makes me a better teacher today. Empathy, compassion and seeing students as individuals with their own experiences is important in teaching. Having lived a former life of struggle has provided me with a perspective that allows me to put myself in their shoes – in the shoes of students who may need me the most. I believe that all teachers start teaching by "playing school". Similar to children lining up teddy bears into neat and tidy rows and standing in front of them to direct their learning, teachers too line up their students to deliver lessons. As children, we delivered lessons to our imaginary classroom by talking at the teddy bears, singing songs and on occasion giving tests. Some of us would even discipline teddy bears and put them in time out chairs. I think of my early years in teaching to be similar in many ways. We teach by modelling our own experiences and mimicking the classrooms that we observe without really thinking deeply about why we teach in this way. I learned a lot from my associate teachers. They provided me with the practical skills necessary to get started with the flexibility to explore and to develop my own identity as a teacher. My personal experiences and my struggles through my undergraduate degree has definitely impacted my teaching and over time, I know that I started to develop a style of teaching that focused not only on the delivery of curriculum content and the development of skills such as critical thinking, collaboration, creativity and communication but also focused on creating a culture within my classroom where students learned to develop their own sense of self, their interests and their potential for lifelong learning. My conversations with Edith Engelberg still resonates with me when I think about how those early conversations allowed me to see a clearer picture of myself and the potential for doing something that I could become passionate about. She provided possibility at a moment in my life when I needed it the most. I often wondered if there would be an opportunity for me to become that person for a student of mine. Teachers probably become teachers for a variety of reasons. Some may teach to share the knowledge of a particular subject with students and others may go into teaching to make a difference in a students' life. I do believe the motivation for teachers must be a combination of both of these factors. We create possibilities for our students and help our students to discover their own purpose. The complexity of this challenge continues to be a curiosity for me. How we empower, foster and support teachers to become reflective practitioners who connects to both the effective and affective teaching of physics and STEM subjects in a manner that provides equal opportunity for all students drives my professional growth as an educator.

According to Brabrand, & Andersen (2006), there are three levels of teachers. In the first level, the instructor is concerned with “what students are” and when students are not successful, students are blamed. The second level focuses on teaching and what the teacher does. Teachers are categorized as either “good” or “bad”. Good teachers focus on developing good instructional practices and deliver lessons that are engaging. Engaging lessons does not necessarily result in deep learning. The third level of teaching focuses on what the student does before, during and after teaching. The teacher not only activates students for learning, the teacher is also focused on the learning outcomes of the teaching (Brabrand, & Andersen, 2006). It is critical to understand that learning is not a passive process and knowledge is constructed through activity (Brabrand, & Andersen, 2006). Reflecting on my experience during my first two years of my undergraduate studies, my instructors could be categorized as either level 1 or level 2 teachers. I would say that much of my learning occurred through independent study. Although information was provided either through didactic lectures or more engaging presentations, the instructional time in class did not provide opportunities for discussions and active learning to sufficiently develop deep learning of concepts. I learned to become an independent learner and to seek out peers to work with in order to learn the material I was presented with. Tutorial sessions in mathematics were useful but only because it provided an opportunity to ask questions about the problem sets and to obtain direction to “complete them correctly”. When I think about myself as a teacher, I would say that I have changed and evolved greatly over the years. I think back to my first three years of teaching and I would say that my teaching was primarily in level 1 and on occasion in level 2. I was more focused on delivering content and surviving the school year believing that very little time was available for me to really think about how students may need to learn. I was the primary physics teacher on staff and all sections of physics were assigned to me so very little collaboration was possible for co-development of physics programming. I also started to recognize that I had gaps in my own understanding of physics concepts despite the degree. I had learned to just accept facts as being true rather than question why and how they came to be. When faced with planning lessons that engages students to think deeply about concepts, it is important to have a strong conceptual understanding of the concepts and be aware of misconceptions. I know that I learned a lot of physics while I was preparing my lessons and I suppose it was during that time I learned that students need moments to “teach” and “talk” about physics with others to truly grapple with concepts.

Today, if asked, I would say that I do not teach – at least in the traditional sense. I have learned to help guide students in their own learning journey. I continue to find ways to inspire students to discover the world around them and to encourage students to realize their own passion and potentially their own sense of purpose. I have learned that teaching is far more than just the equations that formulate a solution to a particular problem. Teaching is a social event where experiences are shared and relationships are built. It is clear to me that my inspiration came from the people I have encountered on my own journey and in return, it is my time to help open up doors and opportunities for others. To create a classroom where you develop a strong understanding of physics concepts while developing skills in problem solving, critical thinking, creativity, communication and collaboration for a diverse group of students to foster a passion for learning is a difficult challenge for any educator.

Assessment and evaluation plays a large role in the classroom. The format and type of assessment and evaluation depends on the subject. In university, subjects such as, Physics, Chemistry and Mathematics courses involved pencil to paper written midterms and final examinations. Problem sets were also assigned and made up a small portion of the final grade. The problem sets provided opportunities to practice problems that may be on the final examination. Problem sets were graded and returned with very little feedback other than a numeric grade. Problem set solutions were posted or available in the reference library to self-assess after the problem set has been graded and returned. Laboratory work was also a part of science courses. Laboratory reports were required for all science courses. The teacher assistant (TA) assigned to your laboratory section would be responsible for directing your laboratory work and also evaluating your laboratory report. In some of the laboratory courses, a grade was assigned based upon the following evaluation. A pre-laboratory quiz, your achieved results based on accuracy and precision of the recipe style laboratory activity you were given to complete and the final report you would submit before you left the laboratory. A few laboratory courses required an oral presentation and some required a “bell ringer” exam where rows of microscopes and specimens were displayed and students were asked a series of questions at each station. Although the laboratory component of the course could be considered an active learning experience, the laboratory activities largely involved following instructions to complete an outlined laboratory exercise that has a “correct” answer to which you would be compared to. There are four levels of inquiry: confirmation inquiry, structured inquiry, guided inquiry, and open inquiry (Banchi & Bell, 2008). The laboratory exercises presented in the first and second year programs were examples of confirmation inquiry. The intent of the laboratory investigation may have been to build skills in scientific investigation and inquiry but the laboratory exercises were outlined in a manner which required all participants to replicate exactly what was outlined. The experience did not present a deep level of learning as potentially intended. In laboratory courses, failure on any laboratory component would result in a failing overall grade requiring the student to repeat the whole laboratory course. This “all or none” philosophy for performance and evaluation created a high level anxiety in students. My experience both in secondary school and during my undergraduate degree involved more evaluations than assessments. In my experience, I don’t feel that many assessment opportunities with effective feedback were provided. For the most part, I had evaluations where mistakes were only indicators of failures and reminders of how you needed to work harder. From this experience, my thinking around assessment and evaluation were already set when I started to teach. A culture of “weeding out students” in the first week to only have “serious” students in physics class and drilling students with evaluations to “prepare” the students for what is to come in their “university programs” is a culture that was encouraged amongst secondary teachers. How do we teach against this “tradition” to create a different environment where all students are invited to learn and is still evaluated in a way that best represents their learning? How do we provide ample assessment opportunities in a safe learning environment that encourages students to take risks, make mistakes, obtain feedback, reflect on their learning and improve?

## Exploring Student Stories

The interaction between learner and teacher is of particular interest in this study. Having received ethical approval, I interviewed two former students of mine for the purposes of this project. My goal is to develop a narrative that represents the interaction between female physics students and their teacher. The narratives provided by the students, I hope, will provide a perspective that will highlight characteristics of their own learning experiences and the critical moments that may have triggered their inspiration to pursue studies in physics and STEM programs. Appendix I contains questions asked during the interviews and Appendix II is an abbreviated transcript of the student responses.

In order to address the current gender gap in Physics and STEM careers, it is critical to address issues in science education K-12. Children use their interests to guide their learning and will also formulate their career goal before secondary school (Hartung et al., 2005). Students have already formulated an interest in science at an average age of 11 years old and as early as 4 years old. (Feist, 2006) In addition to these findings, it has also been shown that children as young as 4 years old have already expressed occupational preferences along traditional sex-type of occupations. (Trice and Rush, 1995) Today, there are many initiatives focused on girls in science and STEM and yet, there continues to be differences in retention of girls in physics and STEM careers. In order to better understand the issues, it seems appropriate to investigate the stories of young women who envision their own future as physicists and STEM professionals. My own personal journey as their teacher intertwined with each of their own stories provides a unique opportunity to discover methodologies in instruction and learning experience that may help to close the gender gap. The role of mentorship in the physics classroom to support female learners and the journey for young women to develop their own identity as physicists and STEM professionals will be explored through this study.

The study will focus on two former female physics students and their experience in their physics programs. At the secondary level, physics is often the course that is required for most STEM careers pathways. For most first year STEM based programs in post-secondary schools, physics is a required course of study. For this reason, I will focus on physics as a way of capturing the student narratives. However, STEM Education seems to better position itself as a way of engaging a broader audience and has the potential to encourage more girls to consider STEM careers. The focus on using science, technology, engineering and mathematics in an integrated way to explore problems that connects to society and the environment to make change provides a real world context that more students may relate to. The subject areas as separate disciplines of study creates a false representation of how problems are solved in the real world. Learning to integrate, blend and merge ideas in innovative and creative ways to solve more complex problems will not only better prepare students for what is to come but also brings relevance to the skills and content areas that they learn. By providing these experiences within the classroom, all students, regardless of former experience, personal circumstance and access to opportunities will have a way of exploring their own potential and interests before finalizing their own career pathways.

The two students interviewed for this project were former students of mine and were interviewed at the end of their first year of university. Alice and Betty were students in my Grade 11 Physics and Grade 12 Physics classes. Both students were interviewed independently and then together to discuss their experiences in my classes, their experiences in their first year of their post-secondary programs and also their own reflection on their experiences that got them interested in pursuing post-secondary studies in physics and engineering.

When Alice and Betty were asked to discuss their experience of high school physics, both indicated they discovered that they enjoyed physics. Alice states that she was always good at math and found that she was able to do well in science so she just decided to "take physics". Betty also indicated that she was also good at math and her interest in physics started in grade 10 when she discovered that she enjoyed the "physics unit" – optics. As a physics teacher, I have found that comfort in math concepts does assist with feeling confident in physics class most of the time. However, I have experienced situations where students who have struggled in math end up making connections in physics that allows for a better understanding of mathematical concepts. This highlights the reciprocal nature of this relationship. I have also taught students who have found math quite easy and found physics to be quite difficult – the application of mathematics within the physics context. Though I believe that mathematics is important in physics because it is the language through which we describe and communicate physical concepts, models and ideas and it enables us to solve problems, I would argue that mathematics alone is not an indicator of ability and potential for learning physics. Betty mentions that my approaches to teaching was different from others and these methods helped to create an interest in physics.

> "You approached teaching a lot differently than the other teachers did – always changing up groups and kind of doing experiments and telling us after… the whole purpose was to explain the concepts. You knew a little about the idea from doing the experiments … made it really interesting… I feel like a lot of teachers really don't approach it that way…" (Betty, 2015, Appendix II)

I believe that students learn best when they have an experience they can relate to. I know from my personal experiences, that I had a lot of difficulty in understanding what the learning was about when I didn't have experiences with what was being discussed. It would be like asking a student in Australia to build and test a better toboggan when the probability of sufficient snow in Australia is highly unlikely. During my elementary and secondary education, I have found circumstances where I didn't know what was expected of me because I did not have a context to what was being asked. Educators make many assumptions about their students – including assumptions about experiences. Problems we pose and projects we ask of our students are often designed with an intended learning in mind but without always reflecting critically about how a student may interpret or understand the assignment. A simple word problem in the eyes of a teacher could be very abstract to a student. To ensure that all my students are provided with equal opportunity, I have always felt that it was important to provide experiences as a starting point to have students explore and discover something that may be familiar to some but potentially surprising for others. By providing context to the learning, conceptual understanding can be built and further extended into new experiences. Teachers must create a common experience for all of their students in order to initiate the discussion and exploration. This builds concepts in a scaffolded way that engages all students no matter what their background. Building confidence in a student's abilities and providing opportunities for success are important. Both Alice and Betty indicate that they felt successful and able to pursue studies in physics. Betty mentions that she felt challenged at times but felt that success was still attainable.

> "I had you as a teacher and I was kind of intimated and you hear things "Ms. Lim-Cole is so hard" – have to do well to get into post-secondary… and I came into your class but it was really fun, it was a challenge but it was fun." (Betty, 2015, Appendix II)

Finding the balance between challenging students and having "fun" while learning is difficult. I have found this balance depends on students and their experiences. It is important to observe students and engage in conversations with them while they are learning to ensure that you are responding to the needs of the students and that you maintain the level of engagement necessary to really challenge students to develop skills and conceptual understanding. Students should be challenged and questioned and face obstacles in their journey to understand something. However, it is also important to ensure that challenges don't become frustrations that students are not willing to overcome. Both Alice and Betty indicate they pursued physics and STEM programs because they felt they were successful at it.

The content within a course can also impact student interest. Teachers must create opportunities to merge student interests, real world applications and the curriculum in interesting ways within the classroom. Alice has always had an interest in music and seeing how physics connects to music inspired her. Later, in grade 12, she speaks about her interest in modern physics ideas in Special Relativity and General

Relativity. Betty also identifies topics such as optics, waves and quantum mechanics. She indicates that she likes concepts that connect together and she felt these concepts connected in an interesting way. Betty also remembers my lessons on vectors and appreciated how the lessons connected vectors to real world activities. My approaches to course design evolved over the years. I used to think that as long as I had a lesson plan for the day, I was prepared as a teacher. I realized that a lesson in isolation was insufficient to engage students in a way that fosters the culture of learning I wanted to create. I realized the connected narratives between content, pedagogy and application to real world contexts were important. Providing students with a storyline that connects their learning to the experiences I wanted to share. I have accepted that most of what I do in teaching physics and science is to tell a story that connects ideas together and makes it relevant for students. I feel that my purpose as an educator is to guide students to wonder and explore the world and universe around them and to support them as they develop the habits of mind necessary to be successful in today's global society.

Alice and Betty also shared some areas of their physics classroom experiences that they did not enjoy. Alice spoke about "measurements" as a concept that she felt was highly repetitive and not engaging. However, when she went to her post-secondary program, she recognized that this skill was highly important and she was able to navigate the challenge in her post-secondary program better than her peers as a result of this experience in high school. Betty speaks about her dislike of electricity and magnetism and electromagnetic waves. What I find interesting about this statement is how these concepts also connect to what she actually states she likes. It is clear from this conversation that I have missed, in some ways, making that connection in my classroom.

Many of the modern physics lessons that were used and adopted for use in my classroom were from resources developed by the Perimeter Institute for Theoretical Physics (Appendix III). I was a teacher contributor for many of these resources and many iterations of classroom testing and feedback were used to develop these resources. Alice in particular makes reference to some of these lessons and indicates that she was most interested in these concepts. As a physics teacher, I have always believed in ensuring that modern physics is a part of what we teach. Newtonian mechanics is a powerful tool that should be used to demonstrate concepts that are still used today – it is the physics that got us to the moon and continues to help us build and solve problems here on Earth. However, it is modern physics that has allowed us to develop the technologies of today, allowing us to navigate by the Global Positioning System (GPS), discover subatomic particles such as the Higgs Boson using the Large Hadron Collider and imagine how we might get ourselves to Mars. Students of today will be our future innovators and if we hold on to teaching the theories and STEM concepts of today until later, we may not capture the imagination of a diverse group of students necessary to move us into the future. If we are truly dedicated to creating opportunities for a more diverse group of students, then we must consider including concepts that may capture more students.

My classroom was structured to help students develop skills in collaboration. I often had students working in different forms of working groups – partners, small groups and large groups. Collaboration in different formats looks and feels different. It was important for me to ensure that my students not only learn the content in interesting ways but to also develop skills in collaboration. I remember my own experience at university when I realized that it is really difficult to do things on your own. I learned that knowing how to work with others and develop strategies that will enable me to work with different work groups is important. I learned how to ask good questions to help to support my learning. I wish I had learned these skills when I was in high school so I made sure that my classroom integrated the development of these skills within the program. Betty describes what she liked about working in groups,

> "When someone would come up with a really interesting approach… It was really interesting to see how different people comes up with an approach to solving a problem… because generally we would only think of one solution… but having different types of people and having different types of learners in the group was very interesting because working in that whole dynamic was an interesting experience. Learning how other people think… also seeing how other possible solutions can be equally correct and are possible…" (Betty, 2015, Appendix II)

These comments remind me that when implementing strategies to support the development of collaborative skills with students, it is important that classroom norms are clearly set and expectations are understood and practiced consistently. Create a structure that starts to set up these norms and over time, as students learn how to engage with each other effectively for learning, you may then provide more flexibility in the implementation of these structures. Appendix III includes some sample tools that may be used to implement some of these strategies.

In my classroom, I have noticed that girls are often quiet and do not always engage in discussions in the same way that boys do. Creating opportunities for girls to take on leadership roles, provide structures that allow girls to have a voice and an active role are important. Alice describes her own perception of girls in science and states,

> "… it really sticks in girls brains to really think that is not really girly thing to do. But I guess it depends really on the environment you are in. When people think of science, they picture a boy in a lab like mixing chemicals and stuff. You never picture a girl.. You think of a guy… like in your head… you didn't really show off if you were really smart because the boys were doing that so you just stood back and let them do that because whatever, you just go ahead and do that." (Alice, 2015, Appendix II)

She indicates there are mental models of who does science but at the same time recognizes that she didn't allow these images to impact her choice. Recognizing that girls have an internal narrative that may play a role in how they engage in your classroom allows you to make instructional decisions that will support girls. Empowering them to speak up and to take on more active roles.

Role models for girls in Physics and STEM are important. Betty suggests that more role models would have helped her come to her decision sooner.

> "You are not really presented with a lot of girls in those fields… like in engineers… you are not really presented with a lot of examples… if I was presented with that early, I would have made my decision faster…" (Betty, 2015, Appendix III)

Positive role models are important for students. Providing ways for students to connect with a variety of STEM career professionals from a diverse background is important for all students. I used to do an annual trip to explore Physics and STEM to help students see the full spectrum of opportunity. I would start the bus tour at Perimeter Institute for Theoretical Physics to explore ideas and current research in theoretical physics. Then the tour would continue to experimental physics at the Institute for Quantum Computing. The final destination would be Physics and STEM in industry. Students were challenged to think about each location and reflect on what excited them and what didn't. They met a wide range of professionals and reflected on where along that continuum they would imagine themselves. I know this experience has been powerful in helping students imagine where their own educational journey may lead them.

Betty mentions the word physics was unfamiliar to her until high school.

> "Physics doesn't really pop up either… I didn't really know what it was until grade 11… You are not really presented with the word physics… I think it would scare some people but I think it would make more people interested…" (Betty, 2015, Appendix II)

The Ontario Science and Technology Curriculum (2007) clearly outlines many physics concepts as part of the curriculum. However, concepts are not explicitly labelled as physics within the curriculum. Betty suggests that using the word physics earlier may help to encourage more students to take physics. During the 14 years I was in the classroom, the school population increased and the number of physics sections also increased. While I love teaching grade 11 and 12 physics, I felt strongly that I must also teach grade 9 and 10 science courses. I felt that I needed to also teach grade 9 and 10 science to better support the physics content in those courses. I wanted to ensure that I supported the teachers in a way that would authentically represent the physics units of study to ensure that students would consider taking grade 11 physics.

Today, we have access to an unlimited quantity of information and facts. It seems appropriate to think about how we deliver our lessons in this new world of information. I have played with instructional strategies such as the flipped classroom. I didn't create videos for students to watch before coming to class as I didn't feel that was appropriate for what I intended but I did ask students to read in advance, create summaries and on occasion view videos for homework. My intent was not to have students fully understand the material on their own but to have students thinking about the information before coming to class to activate their thinking and potentially engage them to think about questions they have as a result of their homework. During class, we would go over this material in different ways – problem solving, collaborative group problem solving challenges, projects, and investigations. Alice remembers this clearly in her description of her experiences.

> "I always really liked the classes and I thought they were well taught…. Like when we had to learn it on our own… that everyone was really frustrated by but that wasn't you being a poor teaching, that was you teaching… saying you are going to have to do this in four months so you better start doing it now while I help you. At the time everyone was like, why am I doing this on my own but it was you trying to help us be better." (Alice, 2015, Appendix II)

Assessment and evaluation is highly important in grade 12 courses. Students in grade 12 physics typically are interested in highly competitive post-secondary programs. I have found that most grade 12 physics students are highly driven students who consistently work hard. As a physics teacher, I have often found assessment and evaluation difficult for a variety of reasons. It is easier to assess and evaluate items where there is a correct answer and a process that is prescribed. Students can be trained to replicate a process and deliver correct answers. However, I believe that solving problems that are authentic means there may be different approaches to the problem. Though most high school physics problems may have only one possible correct answer, it is also important to expose students to scenarios and problems where there may be more than one plausible answer or strategy. Students should develop skills in reasoning and be able to construct arguments to justify their answers and solutions. Developing these scientific literacy skills are important for all students. When assessing and evaluating such open ended tasks, it is important that clear learning goals and success criteria are set. Betty speaks about her experience with evaluations in her post-secondary program in contrast to her experience in my classroom.

> “I would have liked to have a test that is just three questions to prepare you for what’s to come… or even just a full multiple choice test just to get people in that mindset because you are not.. like, people are not taught how to do multiple choice tests in high school and I guess that is for all sorts of classes… so I wouldn’t say that it only pertains to you but maybe all teachers should definitely in grade 12… I guess no teacher really prepares you for that kind of adjustment.” (Betty, 2015, Appendix II)

It is difficult as a high school teacher to think about evaluation the same way that post-secondary programs such as the one Betty is pursing approaches evaluation. High school programs not only prepare students for theory based courses but also the laboratory courses. I struggle with this transition and am resistant to thinking that as a high school teacher, I need to change how I evaluate students based upon how post-secondary schools choose to evaluate. I do not think that giving one test that is fully multiple choice during a high school program would give sufficient practice to see improvements for a student. I have always been a strong believer in providing assessment with effective feedback and with ample opportunities for students to demonstrate improvements throughout a course. Evaluations must consider conversations, observations and products to best determine student achievement. I used to speak about stationary targets and moving targets with my students. Stationary targets are success criteria that never change. Some things just never change regardless of task or content. For example, communicating your findings in an organized manner in a technical report is a stationary target because this process is the same regardless of the task. A moving target may be content specific and only applies for particular scenarios. Students have ongoing opportunities throughout the course to improve on stationary targets and because the moving targets are clearly indicated, students are better able to meet the success criteria set for each task.

Alice and Betty were asked to describe what they felt is needed in order to best prepare students for a STEM program. Alice mentions the importance of the teacher.

> "… you need the right teacher… you need someone who cares about the subject and is interested in it or they are going to be so boring when they teach it… if they don't like it. They are animated when they teach, they are really interested in the subject, and they give you lots of.. like sets you up with the right tools so you have do it yourself." (Alice, 2015, Appendix II)

Betty recognizes that making mistakes is part of the learning process.

> "We definitely have to make the mistakes to learn from them. I want to say that teachers don't allow students to make those mistakes in high school…" (Betty, 2015, Appendix II)

Betty also mentions that smaller class sizes also creates an environment that is more informal which she enjoys. However, she mentions that a larger lecture style learning environment seems more formal and creates an environment which you take seriously. I have always felt the classroom environment and classroom procedures plays a large role in how students engage in their learning.

I am a physics teacher with a physics degree. Not all physics teachers have physics degrees. However, not all physics teachers need to have a physics degree in order to be excellent teachers. Passion for the subject and a willingness to continue to learn are the most valuable traits in a teacher. Though I have a degree in physics, I would say that I probably didn't truly understand many concepts until I had to teach it. When confronted with explaining the concepts that you so easily adopted and use to others, you are forced to face your own misconceptions. Knowing that explaining concepts to others helps construct deeper understanding, I often pushed my students to do the same. Passion and enthusiasm for teaching is important. Genuine excitement about the subject is contagious and students can be convinced to engage in the learning when teachers are energetic. Conversely, when students show interest in the subject you teach and are now committed to learning, it can also energize a teacher and inspire them to extend the experience even further. I have really enjoyed my time in the classroom and have thoroughly enjoyed teaching and working with all my former students. Smaller class sizes do have a different feel that larger ones. When I started teaching, I had a physics class of five students. This class was very different and more individualized programs were possible. As more students started to take physics, class sizes increased and how I taught had to change as a result of that. I was committed to ensuring that every student obtained my support so I intentionally developed a system that would allow me to visit and meet with each student on rotation. I ensured that students worked with their peers on rotation and I circulated around to each team regularly. I often documented our discussions. A template of the documentation process can be found in Appendix III.

Alice started her first year at university as a Physics' major but has since decided to change to Systems Engineering in the fall. She does not regret starting her post-secondary studies in physics but thinks that her experience will make her a better engineer. She is quite passionate about current innovative technologies and quite excited about being a part of a profession that will continue to innovate and develop new cutting edge technology.

Betty is pursuing a degree in Medical Physics and has also decided to study Computer Science. She is in a small program and mentions that she is the only woman in her program in her year. Betty is clearly not bothered by this fact but recognizes there is a need to change this statistic and feels this conversation is important.

Alice and Betty are two women studying physics and STEM subjects to purse STEM careers. Their confidence, assertiveness, resiliency and ambition is clearly illustrated in their conversation with me. My relationship with my students and the ways in which I structured my classroom, delivered my lessons and engaged students in experiences connected to physics in the real world has made impacts on my students' journey into physics and STEM. The teacher I have learned to become comes from a collection of personal, education and professional experiences. I am committed to providing educational opportunities for students and in particularly driven to ensure that students who may not have access to opportunities due to personal circumstances are provided the necessary supports to realize their own potential. My own educational experiences and struggles have helped me to become a compassionate educator who understands adversity and the power of resiliency. I have become a reflective educator that critically reviews my own teaching methodologies to ensure the message and narrative I provide is inclusive and allows for diverse thinkers to engage in the concepts being explored.

## Concluding Reflections

The semi-autobiographical study presented in this investigation provided me with an opportunity to critically reflect on my own personal and professional experiences and how these experiences have impacted my professional growth as an educator. This study provided a way of exploring female student perspectives on physics education and STEM career pathways. The conversations between teacher and student allowed for reflection that has helped me to think about my strengths as a STEM Educator and also identify areas of improvement. The students have indicated that pedagogy plays a role in how they engaged in their learning. They appreciated the development of skills in parallel with building conceptual understanding of concepts. The students indicated that experiences and hands-on learning played a large role in developing their interests. Opportunities to connect physics to their own interests such as music was also important. It was also clear that learning about the mysteries of our universe and how modern physics drives today's innovations and continues to push our humanity to explore and answer more questions excites them. Connecting with our young female students and providing opportunities for them to meet other female STEM professionals are also important. I am a female physics educator and for one student, she mentions that my gender did matter. I am not certain if it was my gender that really provided her inspiration. I believe that all educators have the potential to make change and it is through our collective stories in partnership with our students that we foster our next generation of female STEM professionals.

I believe that teaching is about telling stories. It is about interweaving the curriculum of the subject we teach through a narrative that connects the content in interesting ways, makes connections between the concepts and the world around us, while providing exciting and sometimes surprising experiences. The stage is set to not only “deliver curriculum” but to create a play where teachers and students interact to discover and learn together. The following themes emerged from this study and should be considered when designing a program that support female physics and STEM students.

1. Create a story – design a program that connects to the real world and interest of your students. Be intentional about making connections between strands and concepts. Help students develop curiosity and strategies through which they can explore their curiosity.
2. Provide opportunities to develop skills such as collaborative group problem solving. Support students to develop global competencies in communication, critical thinking, problem solving, creativity, innovation, entrepreneurship, collaboration, and global citizenship.
3. Support students in developing study skills and vary assessment strategies. Help students build confidence!
4. Break down stereotypes! Ensure that you provide opportunities for students to meet and/or hear from female STEM professionals.
5. Support students in exploring different STEM Career Pathways. Help them broaden their options. Not all students have access to role models to help them.
6. Don’t avoid using the word “physics”. Using the word early helps students to build confidence in physics and STEM and breaks down stereotypes.

7. Teach Modern Physics! Students want to engage in topics that are current, relevant, and connected to the world around them. Students want to explore how they could be our future innovators!

Teaching to support girls in Physics and STEM is a complex issue with many factors. This study only presents one story – one narrative of one teacher and her journey with two of her students. As we critically look at STEM education and the role it plays in our society, we must seek to find ways to develop inclusive classroom practices that provides opportunity for all our students. It is through these stories that we start to unravel the complexities of what we do as educators and obtain some possible insights to what we must do to move forward. I challenge educators to critically reflect on your own journey and how your journey connects to the learning journey of your own students.

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## Appendix I

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**Semi-Structured Interview - Individual Interview Questions:**

1. Describe your experience of Physics in High School. What especially stood out? Why?
2. What curriculum areas did you most enjoy? Why? What curriculum areas did you not enjoy? Why?
3. Describe particular lessons in Physics that you remember. Were they good experiences? Poor experiences? Why?
4. Why did you choose physics at University? What inspired you? Explain.
5. Girls are underrepresented in Physics. Why do you think this is the case? What would you suggest as possible solutions to this problem?
6. What advice would you give to girls who are deciding what to study in science? Explain.
7. As former students in my physics classroom, what do you remember about the learning experience? What did you like? What did you not like?
8. What advice would you give me to improve my own teaching practice?
9. If you could turn back the clock to any moment in your educational career to date and chance it, where would you travel time to and why?
10. Describe what your perfect physics course would be. What are the characteristics of the classroom? Of the teacher? Of the school?
11. What advice would you give to younger students who wish to pursue physics and physics related careers?
12. What are your future aspirations? What do you envision as your future?

# APPENDIX II

## Abbreviated Transcript of Interviews with Alice and Betty, 2015

### Question 1: Describe your experience of Physics in High School. What especially stood out? Why?

***Alice:***

I don't know… I picked it mostly because I was good at math in grade 10 and everyone was like oh.. physics is a lot of math and I was like ok I'll take that one. And then when I started take it, it was actually really cool 'cause it sort of explained everything and its really cool when you can watch something fall and you can think about everything that was happening and why it landed. I was picking out my courses and they were all arts courses and I was like wow… I should take some science 'cause I wasn't bad at science. And also my dad was like, you should take some science.

***Betty:***

Grade 9 and 10, you don't really know what physics is exactly…Grade 10 – optics unit – did really well on that test – I actually did really good at this… and I hate memorization so biology was out – I took chemistry too

Coming into grade 11, I had you as a teacher and I was kind of intimated and you hear things "Ms. Lim-Cole is so hard" – have to do well or you else you are getting into post-secondary… and I came into your class but it was really fun, it was a challenge but it was fun.

You approached teaching a lot differently than the other teachers did – always changing up groups and kind of doing experiments and telling us after… the whole purpose was and explaining the concepts.. you knew a little about the idea from doing the experiments … made it really interesting… I feel like a lot of teachers really don't approach it that way… kind of like an investigation… and then kind of like an explanation.. while most of the time, they will kind of like.. give you an explanation, will give you and experiment or something and you will learn about it more so it was really interesting.. not being thrown into it but kind of like discovering things on our own and kind of gave us a lot of independence which I think in most science classes you are not really given that… In terms of what really stood out, I would have to say that the ISU's because normally, you are not really given that much freedom to really like, kind of like creativity and stuff which is really interesting. Doing such a big project was really cool and you had to learn how to work with people which is also a learning experience… It was a very different approach to learning things which I really liked… and I think that is what really influenced my liking to physics.

**Question 2: What curriculum areas did you most enjoy? Why? What curriculum areas did you not enjoy? Why?**

***Alice:***

…because I was good at everything… I kept doing everything… In grade 11 is when I changed. I really liked music and I still do now but when you… I took physics and chemistry and you kind of get deeper into it and I really liked them. And then in grade 12 I liked them even more so…

**Betty:**

"Was really bad at English so that was out of the question – anything that was English, writing… I can't really do.. I'm really bad at it… Only other option would have been a languages because I pick up on languages really fast… but I feel like in science you learn more… it is more ongoing learning process… where as in languages, you can learn more words and stuff but it is not as interesting.. it isn't developing… I guess…

I hate electromagnetism, I don't like all of the theory and stuff behind it.. I hate it.. I have a whole course on it next year and that is going to be interesting… There is something about it that is… I understand it.. but I can't fully wrap my head around it… it is brought forward in such a theoretical way and I can't just wrap my head around it.

As for areas I most enjoy… I really like dealing with wave and oscillations… I find it really interesting with the speed of light and tying it into quantum mechanics… I really feel like those are the two areas where they link together a lot where really find it interesting…

I just like playing music, I don't like performing… I like speaking alone but I can't deal with performing alone. I would never do that thing

Math was really good first semester… second semester was a different story… It was good.. I found that in first semester in calculus is was review but in second semester… every single day was just something new… other than computer science where you were learning something new every day… physics was still kind of review but they were testing us in harder ways…. But calculus was hard… first semester, they were testing us differently than generally what we are used to. One of our midterms was just one question so like you either passed or you failed… so that was just a really big adjustment to make and I really struggled with that in first semester… but I got my act together at the very end which is good and I did fine in the class… In the second semester, I focused on the physics… I did really well in physics so calculus was a little struggle… balancing was really hard… I was really good at time management,,, but it was just a lot of work… it was a lot to take in… and calculus was at 8:30… I didn't like that… I can't really do 8:30 class…"

**Question 3: Describe particular lessons in Physics that you remember. Where they good experiences? Poor experiences? Why?**

***Alice:***

I really liked the sound unit in grade 11 so… It was near the end of the semester and it was part of the sound lab and we had to build a speaker… and it actually worked and I was like wow this is so cool. And then I wouldn't shut up about it and I was like dad I built a speaker today! It was so cool because it actually worked and it was just really interesting and I was like wow we learned it and we did it. Its true… we can see it… and that kind of thing and in grade 12 there was the general and special relativity and we got into the more modern physics and that stuff was so cool. It was just so interesting and

Then we learned a little bit of quantum and then we learned quantum in chemistry and that was really cool. It was kind of explained everything that they just told you that you had to sit with and accept that it was true but they wouldn't tell you why and then you kind of learned really why.

The measurement lab at the beginning of grade 11 was just so long and huge. It was fine but I always make sure that everything was exactly right and it was a lot of measuring and it was just to teach us all skills that didn't really have much to do with the course… but was the fundamentals… but then I got to university and I realized that a lot of people just didn't know how to read rulers properly..

Don't really like the tedious repetitive stuff… Doing things that seem unrelated to anything…

But they are… its actually really important. But in the moment, you think this is stupid…

***Betty:***

I remember the first kinematics lesson when you started teaching us about vectors and stuff and I was like… what is going on… because it was like… it was really like really cool that we were learning like grade 12 calculus way in advance…

Oh, I remember learning about torque… That was like the first time I have ever really felt like I didn't understand something… like I couldn't even do a single question… and that was a big change for me because generally you can ask a friend or watch a Youtube video or read the textbook and learn it but not only did I do all of those things but I just could not grasp the concept of it… I remember being completely unhappy with myself for not understanding it but after I did, I was really happy because that was something that I have really ingrained in my memory as something I didn't understand… and it felt really good to understand… On the exam this year… I was dead set on getting it right and I did.. when it came to learning torque, I knew this… where some of the students didn't learn it in high school…

I remember when we had to measure the work or the displacement from the classroom to the office… we were running around the school and we looked really crazy… just because in general you are not in any class you are not really given real world examples… examples that are real in the moment… you could do it in the classroom but as a school it is larger example… in the classroom it is great but it is not really challenging you to think about doing stuff in the bigger picture…. In no other classes do you get to do that… To be just… kind of see in a bigger picture because you don't see it in a classroom… it is harder to do in a classroom…

I remember lots of group work as a good thing and a bad thing…because there were groups that sometimes I just didn't get along with… so it's definitely a challenge… it was a challenge to learn how to work in a group in grade 11… I remember being in a group where everyone just could not make a decision… and like… you have to at some point so that was.. it was just a like a really good lesson…at the moment I really hated but now I see it as good thing…

When someone would come up with a really interesting approach… It was really interesting to see how different people comes up with an approach to solving a problem… because generally we would only think of one solution… but having different types of people and having different types of learners in the group was very interesting because working in that whole dynamic was an interesting experience.  Learning how other people think… also seeing how other possible solutions can be equally correct and are possible…

**Question 4: Why did you choose physics at university? What inspired you? Explain.**

***Alice:***

When I was little, I said I wanted to be teacher because my mom's a teacher… My sister wanted to be teacher,,, she only wanted to be a teacher because my mom's a teacher. But it stuck in my brain for a while and then when I got further into high school I was like… I don't think I really want to do that…

And then in grade 10 I had a small period where I took civics and I was like, I like arguing with people and I could totally be a lawyer. So I had brief little moment when I thought I could do law. Then I was like… no I don't want to do that. I started to think about it in grade 11 I guess and the whole summer between grade 11 and 12 my dad was pushing me to not be a teacher because he was a teacher and he didn't like it… and he was like… you are smart and you are too smart for teaching and I was like what?

I really like physics… and I thought about engineering and I didn't think I wanted to become an engineer and I don't really know and it didn't really appeal to me… and I really don't know even what they do… I should have looked into it but I really didn't. I kind of really liked physics and I'm kind of stubborn so.. I picked it and said that's it… that's want I'm doing… I don't know… I just said I liked it.. was good at it so I took it.

Me: If you looked into engineering more would you have chosen engineering?

I don't think so… I was looking at it.. I didn't know what I was going to do at all… I was looking at it and I was looking at it and I was looking at all different types and I thought I guess I could do civil engineering and I thought I don't

I met this one girl… you would have really liked her.. she was really keen… but she liked talked to all her profs and I think she is doing… she just finished her first year and she is working at the UBC… I don't' know… don't' know if it is even BC… the big particle accelerator… TRIUMP… she's working there I'm pretty sure this summer because she just talked to people. She was like… I want to be a physicist… I don't' know if I want to do research… that seems kind of lonely.. and I was thinking… it kind of feels weird cause it feels like that is the only career that everyone is thinking of but I know it's not the only career you can get with a physics degree but that is kind of what it felt like. But I kept doing it.

Unless it is a specific with a career degree… everyone is like… what are going to do with a physics degree and I say, I don't know… everything? You can't get a job with a physics degree and I'm like well, physics is one of the highest paying majors thank you very much but I don't know.. I'm just really not thinking about a career right now so it's totally fine doing it and I'm interested in it so why shouldn't I just continue? But there are some spots where Its a little weird.

I think am I even motivated for this? Its really hard… what am I doing now? In high school I did it because you were supposed to… it's a lot clearer in high school because its free and you are younger so you continue to do but then it got really hard and I thought it was really weird because I didn't have a goal in mind and there were some spots where I just really didn't even want to do it. Because in high school when you actually really know your teachers on like a personal level, its harder to let them down I guess because you want to do better… oh there is someone who actually knows my name and can actually tell if you are slacking but your prof doesn't know you. You are just a face of 200 faces that they see three times a week. I guess there is less people watching you so harder to push myself. Its still fine… I still got good grades but I was slacking a lot more than I used to.

I hope I will be more motivated this year with an actually career in my brain. I will feel a lot better…

Both parents are teachers – Wanting to become a teacher came solely from parents being teachers…

We used to play school. I have two sisters so we used to set up desks and one person would be the teacher and we would set up in the living room and set up lockers. We used to play school. We also played store and house… and fairies so… and Harry Potter and horses… we used to play horses a lot. We used to make up games all the time because we didn't have TV. We never played hospital.. We played spies a lot… spies was fun..

***Betty:***

Doing research at the beginning of grade 12 in looking at what kinds of programs and degrees that you can do… I originally did want to go into pure mathematics… I'm good at it… but doing some research and some stuff… can I do this for all of my life? Just Math… I just want some sort of application… At that point I knew I didn't want to go into Chemistry… I was not a fan… so.. I thought about going into physics because it is sort of math based… so that pushed me into making that decision… and leading up to it, I did got between engineering and physics a lot but it was kind of thinking about where I wanted my university experience to be… well… I don't know if that is a good kind of argument but I know that engineers have a lot more courses and a lot more hours in class and I would…

I prefer shorter hours of class and studying on my own than I feel like I kind of have control of my situation… where they don't' have a lot of control… I've seen it a lot this year… their schedules are crazy…

I've seen people have to pick and choose on what you are going to succeed in… they assign you more work than is possible… that is why I decided to take that route… also because you get to learn about way more interesting things like quantum physics and you just get to go deeper into that kind of study which I find way more interesting than just learning the basics of everything…

This year, the engineers at my school do one semester of computer science and I think they just do C++ where I do a full year and java… I like learning more about things and in more depth where they don't really don't get a full understanding of that… I'm not sure they need to… they need to know how to use it…

**Question 5: Girls are underrepresented in Physics. Why do you think this is the case? What would you suggest as possible solutions to this problem?**

***Alice:***

I think that… it really sticks in girls' brains to really think that it's not really a girly thing to do. But I guess it depends really on the environment you are in. When people think of science, they picture a boy in a lab like mixing chemicals and stuff. You never picture a girl and when you picture an engineer you don't think of girl you think of a guy… like in your head, you picture a man being an engineer and a man being a scientist so it's just the kind of thing that throws you off…

and even.. in elementary school… there were the smartest kids in the class and everyone would always think of the boys… they were two guys who were just the smartest… I went to a really small school. There were 27 kids because it was the same group. …and you didn't really show off if you were really smart because the boys were doing that so you just stood back and let them do that because whatever, you just go ahead and do that. I guess in our society, it's just not… I guess we get pushed away from it when we are younger and so by the time you get to high school… unless you are really good at it… you don't see the need to do it. I guess is what happens…

I don't know.. I always did just what I wanted to do so it was just like… I like this so I'm going to it!

Me: Where do you think you get that from?

My mom.. She's a lot like me… because she grew up on a farm with two brothers. She always did boy things when she was younger and she helped my grandpa on the farm all the time. Use the big tools all the time and stuff and so I guess she was always like whatever I can do that.. why shouldn't I be able to do that? I guess that is probably where I get that from… It never really occurred to me that you're a girl… you shouldn't be doing this.. like that never crossed my mind… ever.. I never really noticed it myself but there was… there is a club at [University] called [Name of Club], it's like girls in physics and I went to a couple of the meetings and they were talking about their different experiences and I was like wow I didn't experience that ever…

They had male physics teachers that would like… getting into IB well you have to write an entrance test I guess so one girl did it and your teacher estimates what score you were going to get and he shot really low for her and really high for the guys and she got the really high score and the boys didn't I guess they had a lot of experience with sexism but I didn't. But also my physics teacher was a girl so…

…even when everyone is talking about who is super smart, they are always talking about the boys. Like [male student] everyone though [male student] walked on water. They never talked about the girls.. ever.. I don't know… I never really liked the spotlight so whatever. I don't really like attention drawn to me really…

I was talking to [professor in engineering] and she was saying that in engineering some of the guys can be very cocky and stuff and I said trust me I had engineers in my building… I know.. She was saying how she would give out surveys and she would have them indicate their gender and have them rate where you think you are in all your different subjects and the girls always under rated their abilities and guys were always way overshooting. Maybe it is drilled into you to maybe not like the spotlight but there are some girls who love the spotlight but they are not… not in academia?

…it was more like… I want to do this… and I always pushed myself because I wanted better grades so when they went a little lower I would be upset.

I know that there was one time in French… which was really easy.. We had a test and it was supposed to take the whole period and it only took two minutes because it was so easy… the only thing that slowed me down was the dictation because I had to wait for her to say the words… I finished the test so the time I spent on the test two or three minutes and then I sort of sat there with it because I was like… I sat quietly… and then… this other kid my class… he was French Immersion so he is really good in French… so when he finished his test which was five minutes after me…. He picked it up with a flourish and walked up to the front of the room and you could tell he was being like hey world I'm doing the test…. Look how early it is.. and I was like dude… I finished five minutes ago. But I was just waiting with it because I didn't know if I was supposed to bring it up or not and when I did bring it up I did it quietly and I didn't show off that it was done..

I think if I had a different physics teacher it would have been different… for example… [sister] had [teacher] at the same time I had you and they were doing different stuff…. And she didn't find it as cool as I did. But that may be because she just wasn't as interested. It's hard to tell… if she had been in my class, would it have been different? She's good at math but she wasn't as good as I was at physics.. her grade was a lot lower… we were in the same science class in grade 10 and we were both good in it… I guess she didn't gravitate towards that stuff in grade 11 and 12 and she picked other subjects I guess… She didn't take chemistry… instead… she took drama.. Maybe it didn't interest her as much as it interested me. Or maybe she just didn't have the same teachers.. or the same experience. She didn't hate physics… she was just not hugely interested in it. She was just thought it was boring… yeah… like.. the ball fell… whatever… It is hard to compare when you don't have lessons to compare. We did different labs and stuff… I think they only did a few… I guess maybe because I learned it and then saw it work.  And that doesn't usually happen.  Normally you learn it and that's it.  And for her she just learned it.  But in physics you learn something and then you watch it actually happen and hey… that's so cool.  So the lessons were different.  I don't know.. maybe if she had you she would have liked it more… it's hard to say.  We are different so you know.

***Betty:***

You are not really presented with a lot of girls in those fields… not the teachers because I think all the science teachers at the high school were females.. but just in terms of jobs outside of teachers… like in engineers… you are not really presented with a lot of examples… If I was presented with that early, I would have made my decision faster…

Physics doesn't really pop up earlier… I didn't really know what it was until grade 11. I remember in grade 7 and 8, we had to build a bridge out of popsicle sticks that can hold a certain amount of weight or whatever and that's physics and another example is doing the egg drop and that's physics too.. You're really not told what exactly you are doing and the same kind of goes with the other subjects but with TV and everything, kids know what chemistry is… you play with chemicals… but physics is not really mentioned… and how do you draw a picture of a physicist… we draw pictures of chemists and environmental scientists and biologists

You are not really presented with the word physics… I think it would scare some people but I think it would make more people interested… it would depend of the type of person you are I guess… depends on how it's presented… would depend on how you feel about those kinds of experiments from elementary school…

What I found interesting is that when going into my first year physics class… nobody is that stereotype… which is really funny but I don't know if it's just at my school because we really do have a really small physics program but no single person fits that stereotype…. It's very interesting…

…even you go to a school guidance counsellor and stuff, it is not an area that is addressed… I remember we have a summer orientation day and you go and you pick courses and it is upper year students who are running it and first of all, they didn't even believe that my major even existed and I'm not even joking and you… I'm doing my major in medical physics and I'm also switching into a major in computer science so I'm doing a double major… and yeah and they didn't believe that this major in medical physics even existed so I pulled out the book and showed them… and then you go to kind of like the academic counsellor to approve all your courses and I took the enriched physics stream… they have the basic medical science one and they have a physics for medical sciences and for a deeper look into it, they have the engineering stream and then they have the enriched physics stream which is mostly physics majors but there is an option to take it… and they looked at me and said they were shocked and they looked at me said you really don't want to take this class… that's not really an option.. that is a really hard class… people really don't push it and even at the university… they aren't really pushing it…

I would say that maybe 20% of our class was girls… There is like 4 of us in the whole class… I can definitely believe that because of how the ratio turned out in the class. Hmmm.. that is very interesting… I do think it can be a bias… because I remember I went to one and she loved me for doing it… she told me to take this class and this class… I do think it depends on the counsellor… Both were female so I find it interesting…

**Question 6: What advice would you give to girls who are deciding what to study in science? Explain.**

***Alice:***

> You have to pick things you enjoy. The stuff that when you learn it you are actually interested in it…it's not just because you have a good grade in that class so I should take that at university. It's like… you learn it and wow… this is actually so cool.
>
> You can't do it because other people told you to. You have to do it because you enjoy it. You need to pick the one that you always find interesting. Even when it is the most boring thing, part of you is really still interested in it. Even if it is something that is so silly and mundane… but you still like going to do it. Like measurements… (laughter) Like looking at rulers… there was a lot of measuring but the part I liked about that lab was that you had to be so precise. I'm always a perfectionist about it. At work, at the golf course, you have to aerate the greens and you take a machine and it takes plugs out of it. It's so messy so my job as part of the cleanup crew is to take the backpack blower to get all the dirt off and I actually liked it because it was this huge mess and I got to clean it up. It's almost calming…
>
> There were two girls I met [friend A] and [friend B] and [friend A] went to ISSYP and she was telling me about it and this is so cool! Damn it.. [friend A] is a lot like me in that she is like I'm good at this and I like it so I'm going to do it… and she find everything really cool and [friend B] was a little different. She dropped out of physics after first term but I think she found university very stressful. I guess she was good at it so she was just doing it but when it got hard, she just didn't have enough motivation to continue but… its hard to say…
>
> It's so bad because I'm a woman in physics but whenever I picture science people, like girls in science, I picture the nerdiest person possible. And I shouldn't… but I do… and I was like, I'm going to university and I don't think I'm going to get along with anyone… and everyone will be so different from me but… it's not true at all… There were some who were really nerdy and really shy… There were a couple people who were like what I pictured in my head but there were more people who were not… they are just normal people. They weren't weird… they were completely normal and I was like… shame on me for not expecting that..
>
> Physicists are so weird though. People in physics are just different. It's funny. They are all a little bit crazy… I noticed that in all my professors… they are all just a little… its really cool but they are all a little bit crazy… to do research in that kind of stuff maybe you have to be kind of crazy.

***Betty:***

I would present… showing more opportunities… showing more students who are going into grade 11 and 12 what kinds of opportunities you can have in all of these areas… definitely showed all the different opportunities… which definitely influenced my decision as well… you did show us a lot of opportunities by taking us to Perimeter Institute and Christie Digital and all those places and it definitely opened a lot of people's minds to the options that are out there… Like knowing all the options like the medical physicist at Sunnybrook. Physicists are everywhere and that is not something you are taught… ever… and also in terms of university, they don't push the harder physics classes… they don't… their capacity is like 100 but they put you in a 20 person room because they know it will never get full… they know…

You want more people because it is an interesting concept and having more people in physics with different approaches would definitely be beneficial but at the same time, being in a really small field of study gives each individual person a lot more opportunities. I'm in a second year class of 5 people and I really like really small classes.. The individual attention… you get to make closer connections with the professor and stuff… You want the program to grow and expand but it is nice to be in a smaller field.

I think everyone in younger grades… thinking back to grade 9 and 10… They think that biology and chemistry is so cool… those are the unit that everyone is excited about so I think it's kind of about getting kids excited about the other units… biology and chemistry are interested but no one is excited about learning about optics because no one really knows about it… dissecting a frog… people find it more exciting than playing with a light bulb…

Don't let anyone tell you that you can't take a course or complete a specific degree and don't be afraid of being in a classroom all full of boys. Studying biology and chemistry are great but if you want a smaller experience and generally interested in physics, I would suggest doing that… I would also suggest considering studying something that you don't even know a thing about like computer science because you can end up finding something that you love… I heard so many students who have taken a computer science course or a geology course or something and they are now loving it and top of the class… just don't be afraid of trying something new or take a class is challenging because that is really all its about… I guess at my school, the biology and chemistry classes are really hard but that is just the process of university… they just want to weed people out I guess… 700 people classes is a sad fact but it is the truth… don't be afraid… I think people should just learn how to go for it… it's a really interesting experience.

Its great being able to make a connection with the profs… I've been talking to people who are in the general science stream so they don't specialize until third year and they have been telling me that their smallest class will be 40 people only in the fourth year,,, definitely consider all the options..

Don't be afraid to ask the prof for help.  The prof is there for you.. that is their job… Also connect with your class… know your class… facebook group… group chats… study groups… study sessions… I think that is the best advice… obviously at some point you want to study on your own but everyone will get to that on their own.. they need their independent study time but,,, I find that having a group of people you can ask for help or that they can ask for help from you can definitely… it will reinforce your knowledge in the subject and feeling more confident about what you are going into study because you have those people there for you…

**Question 7: As former students in my physics classroom, what do you remember about the learning experience? What did you like? What did you not like?**

***Alice:***

It kind of built up over everything. everyone thinks physics is super hard… think I really liked was when we would learn something and then actually see it happen. Because it made it real. And I learn from doing… I like hearing about it but then actually doing it to see it.

Or I need to find it interesting to really stick in my brain. So the labs really helped. …we were making a motor in grade 11 and I was with [student 1] and [student 2] and they were just kind of doing it and I was like whatever… they were doing it all wrong and I was watching them do it all wrong and that was never going to work… how was that supposed to move? How do you think that was supposed to work? I let them try it because whatever, they are not listening so I'll let them fail. And they did then I got it done…

When I was in another group with another smart person, I was little bit relieved. It wasn't all on me.. I would ask is this right? And if it failed it wasn't all on me. I need that confirmation… With a lot of the stuff we did, I didn't know if it would work and we would do it and hope… I have no idea if this is right When I'm completely sure about it, I will totally take control but I don't like being the one person that came up with that.

I remember a specific moment in physics… It was the very first time where I was stumped. We were going a lab in grade 12 and you would give us this goal and you had to figure out how to get there… which was really cool.. …my mind was just really blank and I thought my mind was just not really focussing I was thinking for a while and then I realized.. The other group members had some ideas and I think we asked for help a few times but we got there in the end… I guess I just pushed through.. That experience was valuable.

***Betty:***

I didn't like the group work at first… there are some people that I just struggle to work with.. especially when you grasp a concept faster than other people.. that is definitely a challenge… because once you understand it you just want to keep going… but when they want to learn to understand it themselves.. that is a really difficult thing to deal with… Just because you want to keep learning. I'm goal oriented.. you want to solve the problem and get your work done.. waiting for people and trying to teach it to them… it's annoying?

I don't know what other way to say it but in the end its kind of like… and now I look at it… me teaching them helps me understand it and that is a good thing… So it's like a good and bad experience. …not only do you have learn to work with different people with different learning styles and creating the project ideas but you also need learn to work around different people's schedules and how different people approach doing a project because some people actually leave it till the last minute and some people want to get it done right away…

I really liked the different material presented in class… like the videos with Alice and Bob… I really liked that… and then I think the one time, when you used the iPad to do the lectures and stuff… that was really interesting… Especially because it kind of gives you a taste of what it might be like in university and stuff… because sometimes the professors do that… It was interesting to see that… Going to Perimeter Institute was always a really good experience because most.. not many other high school students get to do that… it is really interesting to know about Perimeter Institute and the kind of options are out there and what research is being done and taking it beyond the classroom. I really liked that. It definitely fueled my interest in physics.

**Question 8: What advice would you give me to improve my own teaching practice?**

***Alice:***

I don't know… I always really liked the classes and I thought they were well taught. Not really, like when we had to learn it on our own… that everyone was really frustrated by but that wasn't you being a poor teacher, that was you being a teacher saying you are going to have to do this in four months so you better start doing it now while I help you. At the time everyone was like, why am I doing this on my own but it was you trying to help us be better. The stuff that I read out of the textbook never stuck as well in my brain as the stuff that we did. But if I was interested in it, it stayed there because I was thinking about it. I thought it was good… you learned something and you applied it. It works really well.

***Betty:***

My first midterm was just one question so I guess… not many students don't go into classes like that but from my personal experience, I would have liked to have a test what is just three questions to prepare you for what's to come… when people say that your grades are going to drop 15-20%, they are not kidding so I guess having that experience or even just a full multiple choice test just to get people in that mindset because you are not… like, people are not taught how to do multiple choice tests in high school and I guess that is for all sorts of classes… and then you come to university where it's a 30% midterm and it's a 100 multiple choice questions and people are sitting there not knowing how to even approach this… so I wouldn't say that it only pertains to you but maybe all teachers should definitely in grade 12 or have that 2 question test or that all multiple choice test because you are going to get one of the two… so.. I guess coming into that.. no teacher really prepares you for that kind of adjustment.

Would have liked more time on quantum physics but that is such a complex subject that no matter how much you learn, you might just keep saying that… so, that is really the only one that I would like more time on it.. because you want to keep learning more about it because it's just so interesting…

On the final exams… back then, I thought "she expects too much" but now "no". Just kind of like… it's a good learning experience from the final exams because, the grade 12 final exam were the hardest that I experienced in high school. I would say that you expected too much but I also didn't have the study habits that I do now.. or kind of the focus..

I think that experience was necessary to get where I am now.. I think a lot of people think like me and come out of high school thinking we always do well in tests and exams and you feel really good about yourself and you come to university and everyone is like us… and everyone is also not doing the greatest… it is a real challenge… you have to go through that… you have to learn that you are not going to get 90% in every class…

If you asked me in the middle of grade 11 or 12, I would have said I hate group work and you kept changing up the groups…

**Question 9: If you could turn back the clock to any moment in your educational career to date and chance it, where would you travel time to and why?**

***Alice:***

I don't regret studying physics this past year. I don't think I would have realized that I want to go into engineering without this past year. I don't think I would have been as passionate about it if I hadn't done that. I'm glad I did physics first. I'm not upset about it at all. …if I were in engineering… I definitely would have been in the wrong engineering. I want to do systems design… I would not have thought of that. I would have been in civil or mechanical or something… It wouldn't have been in what I want to do.

***Betty:***

Just comparing how my study habits are now compared to how they were in high school… I would go back to grade 11 and 12 and look at final exams. I could have studied so much more compared to how I'm studying now… but I think that everyone does that… study for three hours and saying you are ready for the exam… I feel like every teacher teaches that in their own way but I find that the issue is that everyone has to find their own way to study cause people all study a lot different… it kind of depends.. I also approach different classes with different study approaches for sure… and I think people have to figure out their own niche for approaches. For some classes I will have my whiteboard and it will just be pure memorization.. cue cards.. others will be practice problems… I do feel that it is dependent on the person. I guess in high school you are really not given that opportunity to learn how to student and find your own way.

I joined a sorority… there is a room we use a room to study but everyone is in different programs so seeing different ways of studying has definitely helped me as well. That has been a big influence.

We definitely have to make the mistakes to learn from them. I want to say that teachers don't allow students to make those mistakes in high school… I don't want to say that they are not as challenging but they get used to the testing style so that helps them succeed on every single one but every single person I've met at university has had a moment of learning that lesson…

It's the nature of grade 11 and 12 where you start to learn that… you start to study more than grade 9 and 10 and you are not at that point yet and you are going to have that moment in university. It's like a good thing and a bad thing… it's a good thing for the students because their grades are going to be fine because they are not going to have an exam that is going to drop them down like 10% but it's a bad thing because they don't have that sort of moment of my gosh I need to get my act together…

I think it also… it goes back to how university courses are structured too.. like I said, in calculus first semester nothing mattered but in second semester it was all new stuff… physics was like… you just needed a deeper understanding than in high school and more calculus based. Even in computer science, because it was learning the basics, you didn't get into the deeper stuff until the end… and then second semester was structured the same way where you learn the basics and then get into the deeper stuff later…

**Question 10: Describe what your perfect physics course would be. What are the characteristics of the classroom? Of the teacher? Of the school?**

***Alice:***

First term was super easy and it was because it was basically like taking high school over again but in a slightly different setting and some of my physics lessons were exactly the same… I had [professor] first term.. so some of those physics lessons were exactly the same as some of those I had in high school and I would leave and I would be like I literally just learned the same thing twice… He used a little bit different symbols and it really bothered me… like he would use W for weight instead of F subscript g and I understand why but it bothered me. And then it changed by the end… I don't even know what I use anymore or I'm all over the place with my symbols.. its awful… I'm pretty sure… I missed and like it was part way though and I was studying and he always used x for displacement and I really miss using d. It was the exact same except where you always did the easy problem first.. you just went to the medium and hard level problems. I don't know if you have ever her of [another professor]? He is a little bit crazy and he is a little bit old. He is funny but he is… umm… [professor] was a better prof I think. But [professor] is not organized… he is a bit scattered.

It's not the same in university because the person who coordinates the lab is not the same person as the person teaching the course but I like learning it and doing it. And it solidifies it. With physics, there has to be a lot of demonstrations. I guess my ideal physics classroom would be lots of demonstrations and examples are important for sure… it's hard to just learn everything without ever seeing it used 'cause when you try to do it yourself, you don't have anything to refer to.

Was really prepared for physics and math… even chemistry.. I had [chemistry professor]... he was my prof and he has a monotone voice and we were in a theatre because they didn't have a chem classroom for us. It was always very warm and he had a deep voice that was really rhythmic so it was really easy to fall asleep to. But it was also a repeat of grade 12 chem… It was all the same… because they are trying to level the playing field. And then second term, we learned some new stuff. Modern Physics was new… actually not all of it… you taught us a lot of stuff we learned.

I looked around when we were learning special and general relativity and …they looked into it on their own but they never learned it in a classroom.

I need lots of examples for sure because I always follow them. I do the first problem and when I catch on then do the rest I think… so it's nice to have something to follow with. Lots of demonstrations to keep you engaged I guess.. to make it cool.. and well… you need the right teacher… you need someone who cares about the subject and is interested in it. They are animated when they teach, they are really interested in the subject, and they give you lots of… like sets you up with the right tools so you can do it yourself. Like when you first learn about forces and stuff you don't like it but you start to think about how different systems work…this is actually interesting… you can make this…

I am more interested when I see it in context to something and with applications. Definitely real world applications are important. There was this one time when we did circular motion and we had to figure out the bank of the road needed to be for a car and the speed of the car and you were like this is what a civil engineer would do when making a road and I was like hey cool application. Okay… it's not just a trig exercise… it actually has a point. Also it makes it more interesting because you are thinking about it more than if it was just a trig exercise. Applications are definitely important.

***Betty:***

I would say a small class because I love smaller classes… 15 – 20 people… and then it would be a like some sort of group work… alternating group work and lecture based… it would be group work with explanation… one day of that… and one day of lectures… to get a balance.. I think it also depends on what level that students are at… As I understand that my class this year is going to be in an informal setting because there are just 5 of us so we are sitting in a room on couches and a whiteboard. It's very small sort of setting but I feel like… there needs to be balance… that small setting is really nice but also being in that large lecture setting creates more serious kind of approach which is great when it comes to like starting a class because you want to be serious starting a class but as you progress more, you naturally become more serious about your learning so you can do more smaller classes and informal settings but I do like formal settings for the first class… the background basis class… gets you more focused.

As for the professor or teacher, I would definitely say kind of connecting things to their own personal experiences. I found that interesting… Sort of like when you would talk about Perimeter and how you would be trying a new learning approach with us and I found that interesting and I had a professor who spent an entire class on what he does for research… and he asked us how what he does applies to what we are learning now. But I find that teachers who does that is definitely more influential on the students than when teachers just talk about the concepts that you are learning and making that connection… obviously you can't do that with every single concept that you are teaching them but it is interesting having… learning about their professor and their research or what we are learning in a high school class is used on science and the real world… I find that influential… especially because when I decided to do physics and chose to major in medical physics I just couldn't do just a theoretical physics I like having more of the application focus so I feel like by adding in that connecting to the real world and how it connects to the science community.. .it definitely influences students.

Medical physics and computer science was not something I thought I would do 5 years ago… I would have laughed in your face if you told me that… I think it is because it is also small… out of 20, only 10 are going into physics. One 3 in medical physics… lots of medical biophysics.. they are in the med sci stream.. they don't do any second year physics classes, their calculus end after first year… they are in lots of bio and chem classes next year… its interesting because there are lots of them. There is 3 of us from my year.

My uncle's an engineer.. most people are in business… so I'm the odd one out… 100% I am… kind of being in a family that hasn't done science, it was definitely a big shock… 5 years ago, I had no idea what medical physics was… what astrophysics was… so I don't think I have ever really… 5 years ago I wouldn't have ever considered it. I remember coming into grade 9 thinking math is really cool and chemistry is really cool. But nothing about physics… just nothing… might have been my popsicle stick bridge and it broke… maybe it was the popsicle stick bridge…

They just tell you to make the bridge.. there was not physics… they are not going to tell you about structures and what makes it better but I guess in grade 8 it can be overwhelming… if even if you presented these are good structures for bridges and then pick and choose… and then why do you think… I feel like… I just remember being told to make a bridge…

**Question 11: What advice would you give to younger students who wish to pursue physics and physics related careers?**

***Alice:***

Don't be afraid to try something. Don't just not take it because everyone says it's hard. You definitely have to keep your options open. You don't want to close doors because you haven't really learned it before. If I haven't taken physics, I don't know what I would be doing now but I wouldn't be liking it as much…

Before grade 11 physics, I didn't know what physics was. No one ever used the word physics… we learned about forces in grade 8 and they did not tell us it was physics… we were just learning forces.. so I never really thought about physics… I knew it was a branch of science I guess but when I thought of science I thought of chemistry and biology…. And that's a very tiny part. When someone things of science, they think of someone in a lab coat mixing chemicals and like microscopes… no one things of physicists.

[A physicist is..] someone sitting at a desk probably… everyone is like Einstein… science.. but I didn't know that he was a physicist… I didn't know what physics was. No one ever really told me about it or talked about it until you were in it.

Me. Would you have appreciated it if you knew what those disciplines were sooner? Younger?

Probably… If they had called it the physics unit and started teaching physics instead of just saying, we are learning about forces… even when we were learning about them, we were learning about pressure or something and I had no context for it or anything and we were measuring in like kilopascals and stuff… and I don't know what this means.. It could have been anything… it could have said unicorns… oh pressure of 12 unicorns and I would have been like okay cool. I didn't even know what it was.

Grade 7 and 8, we started to split up into separate classes of science. It was all the biological stuff… I found that when we were looking at the different systems in the human body and that kind of stuff… I was interested in that stuff because I have a really good memory. We did cells and I thought those were pretty cool but gross. I was really excited to use some sort of equipment… like a microscope… that was pretty cool.

There was one thing we did.. we did an egg drop… but no one really told us that we were learning physics. We did other things like… we brought in different shoes and we had to guess which shoe… we threw the egg against the wall and we dropped it from the top of the school and you had to guess what shoe would hold up best. And I remember everyone was like the fuzzy slipper was going to take it… and I was like, it's the croc. The croc was going to do that the best. The slipper, its going to go right through that… its air.. and it was the croc… I was right. It wasn't till grade 10 science where I thought it was really cool but it wasn't until grade 11 and 12 where I started really knowing and thinking about it…

I didn't like physics because I was doing well in it. I was doing well in it because I liked it.

Music… I used to practice all the time… it was not because I was like I need to be the best… it was because I really liked playing by flute, so I'm going to play by flute because I'm bored… so I'm going to go play… any oh.. this song is really cool so I'm going to play this over and over again. It wasn't really because my parents made me practice or I was a really dedicated musician… it was because I really enjoyed it.

I picked flute… I picked it because I really liked it. And I continue with it because I really enjoy it. With physics it's like.. it's so tedious to have to go do your homework but whatever, I like it. Unless it's the same problem over and over again. Which is why I never did my math homework because I don't have to do the same problem 6 times.

Me: How about practice problems…

Some students really need it. Some need to do the 6 problems and some might still not get it. I remember in grade 9. I had [math teacher]. She was my math teacher and she would assign homework and she would not check homework. Why am I doing 20 questions of math every night if she is not going to look at them and I didn't really have to do them. And then there was this one class where I was just sitting there… it was our time to do homework.. and I think someone said… She's not working and I think [math teacher] said, well she doesn't really need to… she was like, I know you don't need to do your homework… and yeah, I was like, it's kind of boring and I'm not going to do the same thing over and over and over again. I don't have to factor the same binomial 6 times.

Sometimes I read.. but it was a book for pleasure. It wasn't a math book..

We used to go to the library… Between me, my sister and mom, we would have the maximum number of books we were allowed to check out from the library at one time and we would have a receipt like this long and we would just blow through them and we would go back and get other ones… We had TVO kids so when TVO kids was over, you had to find something else to do. We had a four acre forest and some horses so we would play outside and we would make up games and we would read books.

If my math teacher would have been like, here I would like you to do this worksheet, and it was all really difficult problems, I would have worked through it but I wouldn't have sought out a difficult problem sheet on my own. Or if they recommended that I go out and look for hard problems… I might have tried to look for one or two but it would not become part of my day.

I would have become more interested if someone handed me something and said look at this real world application of something I just taught you and hey cool… I know how to do this?

***Betty:***

Not be scared. The material that you are really learning is not really talked about in everyday conversation.. not that chemistry is always talked about… but if you talk about atoms and bonding people will kind of know what you are talking about but if you are talking about Einstein's Theory of Relativity, very few people will pursue a conversation in that… don't be scared about the concepts you are learning because at first everything seems very overwhelming for sure but like people will get a handle on it… you will wrap your mind around it… it might just take a little longer.. and I feel like that is also a big thing about why people don't really like physics is because like, the first time you are learning about the Theory of Relativity, …in high school and you are not taught how to process things and take that time to fully understand the material … not taught how to take the time to fully understand the material whereas in university you have to understand this or you won't be successful in the course. You need patience. It is okay to not understand the first time.

People need to know not to be afraid… especially girls… you will be in a male dominated field until more girls get into the field…

There is a lot of pressure.. .going into second year being the only girl going into physics… that is definitely a lot of pressure to succeed. Like in terms of first year, there is some pressure there was 4 girls in the class but they were in medical sciences so they were not required to take the class whereas it was me and the guys that were required. There is pressure in study groups when you are the only girl in a study group of guys that are all in physics …I am a really social person and stuff like that doesn't really both me… what they are really scoring on their exams doesn't matter to me… I'm focused on what I am achieving and what I want.

I think it does depend on the person but because I am so focused on succeeding in my personal level it doesn't' really bother me. I do remember when… This year I'm department representative for my year, when I was being interviewed for that position by the physics association people, it was all guys… that was really intimidating… like this year, the top three positions are all guys so it is very intimidating and they were shocked that it was a girl applying for the position. Especially at [university], everyone seems to be quite open. Well as other physics classes of 150 people, is different. The program is small so they are really happy when they see a girl in it.

This year, both professors for physics is male. Next year I think four of the 6 are female. They do have a lot of females in the faculty which is nice.

Having seeing you in that role and connecting with Perimeter and connecting me to [medical physicist],,, that's really interesting… she was really excited to meet me too… yes… girls in physics… I think that would have made the difference.

Me: Is it the connections that makes the difference or me being a woman that made the difference?

I think it was you being a woman that made the difference… I do.. like.. .yeah.. I think I would have been more hesitant to go into physics if you were male… just because… like you automatically think that engineering and physics is male dominated field… so if your first experience with a male, then it influences how you feel about the field of study… rather than if it's a female because you think I can do this too.

Me: Let's just say I'm male…There are many male physics teachers and they can't change that.

Needed someone to push the career options and show how there are women are in these fields so you get an idea. Role models are important – access to women physicist and women engineers.

I think that going into grade 12 physics… generally most students in that class are generally pursuing a STEM career so it's kind of showing them that physics is an option. I think majority of our grade 12 physics class went into science or engineering or something…

Me: When is the critical time to provide students with this information?

Grade 10… that is… grade 10 is where you are planning on grade 11 and 12. And that will influence where you will apply to university. Grade 10 will be the prime time to influence. But I also think that other teachers and guidance don't really push physics at all. Like generally, people just go biology and chemistry. Careers class too.

Me: How about Parents?

I would have been more open to the idea if there were closer family members in science and engineering. Especially because he is an engineer at Ford… I don't want to work with cars… Alice says she does… Yeah… I wouldn't want to do anything with cars so I think it was a slower process. Hearing him talk about what he does did also influence me as well because he was also the only science person in my family. He also went to [other university] and I was trying to decide between [current university] and [other university] so I did talk to him about his experiences. I do feel like if one of my parents were in math or science I would have decided faster… they still don't get it… half of the time they ask me what am I going to school for?? It's been hard…

When I was accepting my offer and stuff they were asking are you sure this is what you want to do? They don't really understand it. Programs have changed a lot. They always wanted me to be a lawyer and go into business but I think that it was hard for them to accept. They wanted to make sure it was right.

Parents are supportive of the decision making. It is interesting especially into the transition into first year because my parents don't really understand that my grades were going to fall… and they don't understand that… it is common to fail an exam… picking and choosing what class to succeed it… when I don't them how I was doing in some of my classes… that was how everyone is doing… they thought that if I was in political science, my marks would be better.

**Question 12: What are your future aspirations? What do you envision as your future?**

***Alice:***

> Recently, it was kind of like… thinking back…I was interested in the environment and new technology. I kind of put it back to grade 12 chemistry… [Chemistry teacher] showed us "*Who killed the electric car?"* (Paine, 2006) and I was just sitting there thinking those people are just so dumb. Why would you do that? Everyone loved it and it's really good and I was just getting mad because it was just so ridiculous. Everyone is just doing that for money… it doesn't' matter how much money you have when we run out of oil… I don't really care if you are rich… if the world is done… I was just kind of mad… someone should change that. And more recently… I was like… wait a second… why can't I change that. It goes even farther back, I was reading… there is this series called the "*Uglies"* (Westerfeld, 2005) and it's a science fiction series… they are go good… anyways, I read them because my neighbour recommended them to me and there was all this really cool technology and this stuff was so cool. He had a book called bogus to bubbly and it was just him explaining the technology of where it is in our world today. And I was reading about it and I thought it was just so cool. It was a really small book but it was really cool and it was interested in it and was like this technology is super cool. SO I guess I was always really interested in innovative and modern technology. I was 13 when I was reading about that and I found it interesting. But just recently, I was like wait a second of course I can do that. That is what I should go into. I don't know why I didn't think of it as a career before. I guess I just stuck it in the back of my brain and was like, I want to do something with green technology but I never thought deeper about what I would do and how I would get there.
>
> I'm really interested in electric cars and always have been. Last summer I was with [Betty] and her aunt and her aunt was driving an electric car. And the whole time in the car, I was asking her all these questions about how it worked. What was it like to drive..
>
> It's just such a good idea and its ridiculous that it hasn't become a bigger idea sooner. I guess I just want to be in that and be at the forefront of that. If I could… I find it really interesting..
>
> My mom is trying to make me… she changed her mind like three times.. you don't want to make a huge decision and like change your mind again in four years… and she is like it's okay to change your mind… she changed from art to geography because my uncle was like, you are not going to get a job with art… and then she finished her geography degree and she was like I don't like this… I can get jobs with this but I'm not going to enjoy them… so she went to OCAD and did art and then she was like okay… he was right… I

can't get a job and so she went to teacher's college and actually loves her job…but she was saying its okay to change your mind but you need to have another plan. So I was like, well mom… I have no idea what I want to do but I think this stuff is really cool and I would like to work here.. outside of that, I have no idea so I thought of the kind of job.. like what would I be doing exactly… so I was like… I want my job to be challenging… probably… obviously, it will be in STEM. If its going to be challenging it will have to be in STEM because what else is hard?

Me… I don't know… writing a novel is kind of hard…

I don't' know… I want to solve problems… use logic and then be stumped… I want to work… I don't want it to be easy… I want it to be hard. I want to help people, I want to do something better. I'm interested in innovative technology and stuff so I think that would be cool. In the future, I would hope to be working as an engineer somewhere on some new really cool technology or something with some big..something that is really going to change something finally… they put up a solar farm on the [rural road], I pass it everyday… but that kind of thing. Like improving that technology and making it more accessible for everybody. For now, it's out there but it's not very efficient and it's not very cheap so a lot of people don't use it. My dad told me about it but they are making some solar films and they are putting it on windows and stuff… how cool is that! If that actually blows up, it would be really cool!

I guess when I'm looking for a coop job, I'm going to have to look for a company like that. I was like… maybe I should be in engineering because that is really what I'm describing. Although, there are other ways of getting there… there are other ways to do that job but that was the most direct path and I was like well maybe I should switch while I'm still in my first year and my marks are high…. Before they drop…

I was expecting it to be harder. And I enjoyed it. The last week of finals, they were all put in one week because the [university] hates their science students. So I wrote 1 on Monday, 2 on Wednesday, 2 on Friday and 1 on Saturday and then everyone was like they were done on Friday but I had a music exam tomorrow. But it was fine.. .it was a music exam, it was music history so I studied in the morning, I went and wrote it and I finished the course and it was fine. It was so easy.. I knew everything.. it was awesome… I loved it but even that stuff, I remembered it because I thought it was cool. I think it was Wednesday and I called I called my mom, it was right before… I just finished my… It was because my physics exam was so difficult… and I walked out and I was like… I had to go study for the next one because out of my really hard modern physics exam, that was on Thursday and I didn't have another exam till Monday so I left because I didn't want to sit in a room so I went for a really long run and when I got back I just really busy so we went out and played Frisbee and we went out. But then on the weekend I was like I needed to study but by then I was like okay… I couldn't do that after the physics one, I couldn't go for a really long run because I had to study for my lab exam I had that day at 7. So it was that kind of thing that was really hard. That was when I called my mom…and all my friends… I'm not the one that usually breaks down… its all my friends who frequently had breakdowns and I'm the one usually sitting with them to help…

***Betty:***

I want to complete my degree and it kind of depends on where I'm at and how I feel after I completed my degree. I may try to get a job in computer science because it is easier to get a job combining computer science and physics. I kind of want to see where that will take me for a few years and then… After a few years, I will probably come back and do a joint MSc and PhD program in medical biophysics and I think the program time is 5 years and I really want to look into that and I know it may even be shorter depending on what your fourth year physics marks are. Also possibly, MSc and law degree with computer science and see where that takes me. I think eventually, I would like to be working in a hospital setting because I really did like that when I went to Sunnybrook. Working in a big hospital like that I would really like rather than.. but I don't know what sort of options there are. Especially with a culmination of the double major, I would definitely like to see what's out there… Hopefully in a few years, I might be in grad school. I've emailed a bunch of professors and they won't take on first year students. [Medical physicist] said after second year she told me to contact her and she gave me some research programs I should apply to and then get my computer programming up to speed. One of my professors, in my introduction of medical physics program, he just got a huge research grant and he is doing all this cool stuff so I really want to make a good impression and do well in his class because he is one professor that I would really want to do research for. I'm really interested in that. And the hospitals also have so much to do in that sort of biophysics and medical physics area. It's just sort of figuring out if I want to do research in that area or do I want to do computer science. Even though everyone is starting from the base class but a lot of guys in that class took computer science in high school and they code on their own time. I think finding a summer position combining the two out be pretty hard. Deciding on what sort of area you want to do.

## APPENDIX III

## Sample Lessons and Resources

The following lessons were mentioned in Alice and Betty's narratives.

**Perimeter Institute for Theoretical Physics Resources**

**https://www.perimeterinstitute.ca/outreach/teachers/class-kits**

- Process of Science
- Beyond the Atom – Remodelling Particle Physics
- Challenge of Quantum Reality
- Everyday Einstein: GPS & Relativity
- Measuring Planck's Constant
- Mystery of Dark Matter
- The Physics of Innovation
- Revolutions in Science

## Collaborative Group Learning Resource

Think of your group as your learning team - the people who will help you learn science. Every student is expected to take-up a specific role within the group and to carry out the responsibilities listed below. Members of every group will evaluate one another on their performance in their respective roles. Roles within a group must change for each new task or activity. (Modified from meyercreations.com)

# Group Roles

**Group of 3:**

| Actions | What it sounds like |
| --- | --- |
| **Manager**<br>• Make sure everyone has read the initial instructions before starting.<br>• Direct the sequence of steps.<br>• Keep your group "on-track."<br>• Make sure everyone in your group participates.<br>• Watch the time spent on each step. | *"Has everyone had a chance to read this before we continue?"*<br>*"Let's come back to this later if we have time."*<br>*"We need to move on to the next step."*<br>*"Ralph, what do you think about this idea?"* |
| **Recorder/Skeptic**<br>• Act as a scribe for your group.<br>• Check for understanding of all members.<br>• Make sure all members of your group agree on plans and actions.<br>• Make sure names are on group products. | *"Do we all understand this diagram?"*<br>*"Explain why you think that."*<br>*"Are we in agreement on this?"* |
| **Speaker / Motivator**<br>• Speak on behalf of your group when called upon in class discussions<br>• Help your group avoid coming to agreement too quickly.<br>• Make sure all possibilities are explored.<br>• Suggest alternative ideas.<br>• Energize your group when motivation is low by suggesting a new idea | *"What other possibilities are there?"*<br>*"Let's try to look at this another way."*<br>*"I'm not sure we're on the right track."* |

**If you have more than 3 members to your team, the forth role will be the assistant manager who will help with any additional tasks that the group feels are necessary for success.

**In a group of four**, the addition of the *Organizer* can be added.

| | |
|---|---|
| **Recorder** | • The groups' whiteboarding exercise is documented in paper form as a final draft of the group's discussions.<br>• The recorder must ensure the voice of all group members is included in the documentation. |
| **Speaker** | • Is the spokesperson for the group. If the group encounters difficulties, this is the person who formulates the question to ask.<br>• When the teacher comes around the check the progress of the group, the speaker is the initial point of contact with the group. |
| **Manager** | • The Manager is in charge of time management to ensure the task is completed within the time allotted.<br>• Ensure that each group member understands before the group continues.<br>• Ensures that all members are on task and engaged in the activity/discussion. |
| **Organizer/Skeptic** | • All equipment and materials must be accounted for during the task and returned at the end of the task.<br>• Ensure that each group member has an opportunity to contribute to the task.<br>• Be a critical voice. Ask questions! |

### Seating

When working in groups, please sit at the desks so that you are facing each other. You will need to adjust your seating so that all members of your group can be a part of the discussion/activity. (See Figure 1)

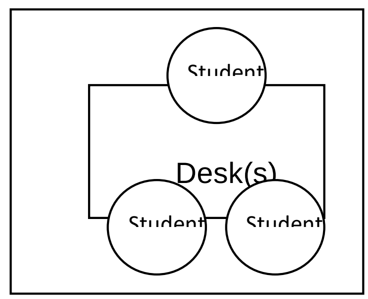


Figure 1: Example of student seating

### Whiteboards and Discussion

One of the best ways to share work and ideas is using a whiteboard and your group's common workspace. This is much easier than all huddling around one sheet of paper. Please use these regularly!

Focused discussion on the task is highly encouraged. The teacher will continuously listen in as you work through the activity. The teacher's role is not to provide answers but to be an observer as your team works through the problems. The teacher will ask questions to help guide your learning. Don't worry about "right answers". This process is about making mistakes and working through your ideas for stronger understanding. Don't be afraid to take risks!

### Use of Clickers

Clickers refers to letter cards on a key ring that students can use to communicate responses. The template is provided in this document. Clickers will be used throughout the course for ongoing formative assessment. It is important that you participate in these activities as it provides essential feedback for yourself as well as for the teacher. The goal of the clicker is not to evaluate your learning but to provide valuable checkpoints for your learning. Making mistakes during the learning process is important! The classroom is a safe place to make mistakes in order to obtain better understanding of concepts to be learned. Embrace your mistakes! Learn from them!

### Group Assessment Procedure

The feedback system for collaborative group work is outlined below.  Work may be assessed for a combination of completion, knowledge and understanding, thinking and inquiry, application and communication. The specific combination of the categories will vary depending on the task. Most group work is treated as assessment – feedback from me on how well you are doing with the new ideas. Only certain tasks will count as evaluation towards your final grade. You will be provided with opportunities to develop your skills before an evaluation is completed.

The scale provided below is not intended to align to a "grade" but rather provide quick feedback to student working groups in an efficient manner so that this process can be complete frequently and quickly throughout the classroom activity.

The scale is also used for self and peer assessment practices as students use the same scale to think about their own work and their peers.

| | |
|---|---|
| **0** | For absent or totally unacceptable work.  Students are encouraged to complete work and to catch up on missed work. |
| **1-2** | Seriously deficient and lacking in fundamental understanding.  The effort put in towards completing this task was minimal.  Students are encouraged to ask questions within their peer group and seek extra help to support their learning. |
| **3** | Shows basic comprehension but requires improvement.  Group must formulate and ask more questions to complete the task with more focus.  Students are encouraged to provide more details in their explanations and discuss thoroughly before consolidating their ideas.  Students are encouraged to work together more effectively and discuss all ideas from their group members. |
| **4** | Good work which meets the expectations.  The activity is completed with success.  Questions were asked with clear focus.  Answers are clearly explained and demonstrates a strong understanding of concepts.  Students are encouraged to extend their learning into new contexts.  Students are encouraged to think about the limitations of their solutions and to provide potential alternate solutions to the task/problem.  Students are to work on making stronger connections to previously learned ideas and create new questions for further investigation based on their present learning. |
| **5** | Exceptional work!  Demonstrates a thorough understanding and examination of the topic.  The question is thoroughly and thoughtfully answered.  Ideas are extended into new contexts.  Students have identified limitations of their solutions and have included innovative alternate solutions to the task/problem.  Connections are made between previously learned ideas.  New questions are formulated for further investigation. |

# Helping Groups Learn

Name: ______________________ Date: ______________________

Recorder: ____________________

Manager: ____________________

Speaker: ____________________

Organizer: ____________________

[C][K/U][T/I][A]: 0 1 2 3 4 5

Working in groups is a skill that must be examined and practiced in order to improve - just like any other skill. In the working world, your skill in teamwork will have a great effect on your future success and happiness so an investment of time and energy now will reward you greatly in the future. (Modified from meyercreations.com)

1. Describe the behaviours or habits of the members of a well-functioning group.

We have all experienced difficulties working in groups. Sometimes, the challenge comes from within – for whatever reason you, as an individual, are unable to contribute effectively to the group. Other times, another group member may make the proper functioning of the group difficult.

2. Think about the reasons why a group might *not* function at its best. Make a list of the reasons in the chart below – be specific. However, do **not** mention the names of any individuals. This is **not** a critique of your current group.

3. Discuss some concrete actions members of the group can take to help each situation. Record your actions and the class discussion in the "Actions" column.

| **Reason** | **Actions** |
|---|---|
| 1. | |
| 2. | |
| 3. | |
| 4. | |
| 5. | |
| 6. | |
| 7. | |
| 8. | |

4. Individually, reflect on the list of reasons and try to determine which might apply to you! Be brave and jot down which reasons they are (you don't have to show the others!) – it is important to remind yourself what you might need to work on.

5. Individually, reflect on the list of actions. Which ones are you comfortable carrying out? Which ones should you encourage yourself to try more often?

# Introduction to Collaborative Group Problem Solving (CGPS)

The purpose of this problem solving strategy is to provide you with a process that helps to solve problems. The focus here is thinking about the problem and planning **before** implementing any action. It is **very** important that you complete each step in the given order and avoid the temptation to jump ahead (especially to the math work). The manager has the critical role of ensuring this. The solution sheet will help to keep your group on track – be sure to fill it out as you go.

**Best way to work**: As a group, start each step by jotting down ideas on the whiteboard. When they are agreed upon and understood, the recorder writes out the good version on the solution sheet. The group should agree on and understand everything that is written on the solution sheet. (Modified from meyercreations.com)

**Set-up**

**A. The Picture**

- Draw a clear diagram showing what's happening with clear titles and labels
- Attach the important information to the diagram using simple phrases
- Make any important measurements
- Attach the unknowns to the diagram if possible
- Indicate the coordinate system and sign convention when appropriate

**If this step is complete, you should never have to refer to the problem statement again.**

**B. The Question**

- Create a specific question that will give the answer to the problem.
- Indicate what you will need to know in order to answer this question.

**C. The Plan**

- List any important concepts or ideas involved in the solution.
- Outline the key steps in solving the problem
- List any useful concepts and/or equations and any other relationships you will use. Provide reasons for why these may be useful.

**Have you carefully completed all the previous steps? If not, go back! Note that you should not have done any real science/math work yet. The previous set of steps helps to understand the problem or task.**

**Execution**

**D. The Work**

- Create the specific concepts and/or equations you will use –write them down with a simple statement explaining what you are doing. If your challenge does not require equations, explain your reasoning and solution to the challenge problem.
- Perform the work! Perform any algebraic manipulations first, whenever practical.
- Verify the units of the final derived expressions.
- No conclusions to your problem yet! No number crunching yet!

**E. The Results**

- Relate theory to your findings. Discuss how your results relate to the concepts.
- Substitute numbers into your manipulated equations and calculate a result.
- State the final answer in response to the question you created.
- Write brief statements explaining why the answer seems reasonable in size, direction and units.
- Explain your findings and provide explanations for your results. Critically think about your outcome. What improvements can you make? What would you like to know more about?

Name: ___________________________________

| Recorder: ____________________ |
|---|
| Manager: ____________________ |
| Speaker: ____________________ |
| Organizer: ____________________ |
| [C][K/U][T/I][A]: 0 1 2 3 4 5 |

**CGPS Challenge Title:**

# TOTAL: /20

****An example of how work may be assessed.**
**STATIONARY TARGETS** (Modified from meyercreations.com)

Self-check the following items.

| Criteria [T/I][C] | Yes | No |
|---|---|---|
| Picture completed | | |
| Question clearly stated | | |
| Plan clearly described | | |
| Work clearly shown | | |
| Results clearly calculated and explained | | |
| Error was discussed | | |
| All group members were active participants | | |
| Proper use of equipment and materials | | |
| Report is written using appropriate scientific language | | |
| The challenge task was completed and tested by the teacher | | |

| Criteria [K/U][T/I][A][C] | Score |
|---|---|
| **Picture: [C]**<br>• Clearly describes the set-up of the challenge with scientific diagrams, titles, labels and descriptions. | /5 |
| **Question: [T/I][C]**<br>• The challenge is accurately formulated into a scientific question. | /2 |
| **Plan: [T/I][C]**<br>• Based on accurate understanding of theory.<br>• Clearly demonstrates a plan that potentially will be successful. | /5 |
| **Work: [T/I][A][C]**<br>• Execution of based on the original plan.<br>• Modifications were implemented when required.<br>• Clearly demonstrates an understanding of relevant theory.<br>• Calculations were completed clearly and explained. | /5 |
| **Results: [T/I][A][C]**<br>• The final test for the task was completed.<br>• Results of your final test was evaluated and discussed.<br>• Error is discussed and improvements proposed. | /3 |

**Comments:**

**The challenge of collaborative group learning is that it is difficult for the teacher to be a part of every group to engage in facilitating each team at all times.** When teaching in an classroom environment where team based learning is occuring, ongoing check in with each team is critical.

Teachers preparing for group learning should prepare some questions they will use as prompts throughout the lesson. The teacher must circulate and check in with each team ready to engage them in discussion, questioning and prompting to continually push their thinking.

Another way of checking in with students is to use “clickers”. The template for clickers has been attached. Each student would get a ring with “clickers” and as the teacher poses check in questions, each student is asked to raise their response. This process provides a very quick visual of where each of your students are. As an extension, the teacher may ask students to partner with someone with a different response than their own and discuss. Promoting a classroom environment which encourages taking risks where students embrace mistakes and discuss actively is critical to group learning classrooms. (Modified from meyercreations.com)

| | | |
|---|---|---|
| A | C | E |
| B | D | ? |
| T | F | |

Student/Group: ______________________________ **L. Lim-Cole**

Activity/Assignment: ______________________________ **Science and Physics**

Date: ______________________________

# Conversation Assessment Tool

**Intended Learning:**

- ☐ ______________________________
- ☐ ______________________________
- ☐ ______________________________

**Questions to Ask:**

- ☐ ______________________________
- ☐ ______________________________
- ☐ ______________________________

**Look for…**

| Look for… | Comments: |
| --- | --- |
| **Communication:**<br>☐ Clearly communicates ideas.<br>☐ Expresses and organizes ideas and information.<br>☐ Used proper vocabulary in their communication.<br>☐ Vocabulary was used accurately and in context to the learning.<br>**Thinking and Inquiry:**<br>☐ Understands the process through which the learning occurred.<br>☐ Develops a clear plan to initiate their inquiry.<br>☐ Describes the connection between the process and the development of the solution to the problem.<br>☐ Reflects on the outcomes of the learning.<br>☐ Makes connections between outcomes and the learning.<br>☐ Proposes reasons for the outcomes of the learning.<br>☐ Analyzes the outcomes and critically reviews the process to make improvements for future learning.<br>**Application:**<br>☐ Demonstrates an ability to apply concepts learned to develop solutions to the task/problem.<br>☐ Uses concepts learned in creative ways to develop innovative solutions to the problem.<br>☐ Makes connections between past learning and continues to apply concepts to present tasks/problems.<br>☐ Makes connections to real-world application (society and the environment).<br>☐ Considers extending the learning into new contexts.<br>**Knowledge and Understanding:**<br>☐ Accurately states concepts learned.<br>☐ Demonstrates understanding of the concepts learned. | |

| Additional Conversations and Notes in Collaboration with Students | |
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| **Next Steps** | |
| | **Comments:** |
| **Signatures:** | |

## APPENDIX IV

## System Plans for STEM Implementation

The document in this appendix reflects work created by a team of educators at the Durham District School Board and may not be reproduced in any way without the expressed permission of the Durham District School Board. As the Science and Technology Program Facilitator (K-12), I was challenged to lead a team to create and implement a system STEM Education Plan. Superintendent Jim Markovski and Superintendent Luigia Ayotte provided ongoing support for this initiative. Alfonso Garcia, Mathematics Program Facilitator, Brian Errey, Numeracy Coach, Carolyn Tsai, Numeracy Coach, Alecia Chor, Numeracy Coach and Secondary Science Department Heads (Jeff Dalgarno, Dorthy Lai, David Wells, Dawn O'Neill, Rosalie Krem, Carmen Chan, Dimitrios Melegos, Suzanne Scanlon, Greg Wisnicki, Bill Grainger, Lynn Gittens, Eric Webb, Marci Cascanette, Chris Howes, Steve Park, Beth Godby, Ed Gnyra, Eric Klatt, Bill Blackmore, Brad Smith, Jane Kennedy and Stephanie Hale) assisted in critically reviewing the plan.

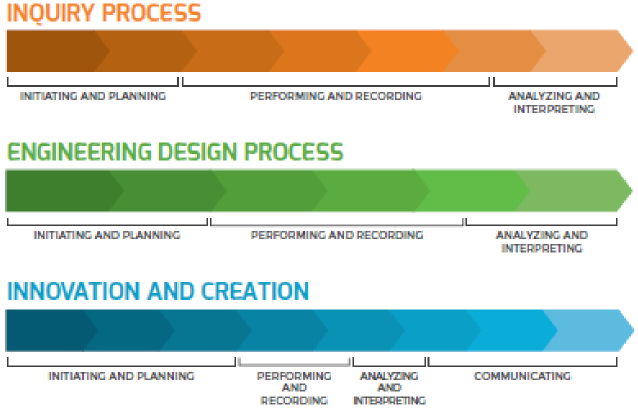
As the Science and Technology Program Facilitator (K-12), I have spent the past three years working on developing and implementing the STEM Plan in the Durham District School Board. Resources and supports for schools were created to support the implementation and ongoing partnerships were developed to enhance STEM programs in schools. A lot of time was spent reflecting on my own teaching practices, researching, and discussing best practices in teaching and learning with mentors and colleagues. Student perspectives were incorporated as a result of my conversations with former students in preparation for this study. STEM Schools and Master Teacher Programs in Buffalo State, USA were also visited and outcomes from these visits were used to inform the creation of this STEM Plan.  A review process is currently in place to update this plan.  Ongoing system data is being collected to measure the outcomes of this plan.

# DDSB STEM Education Plan

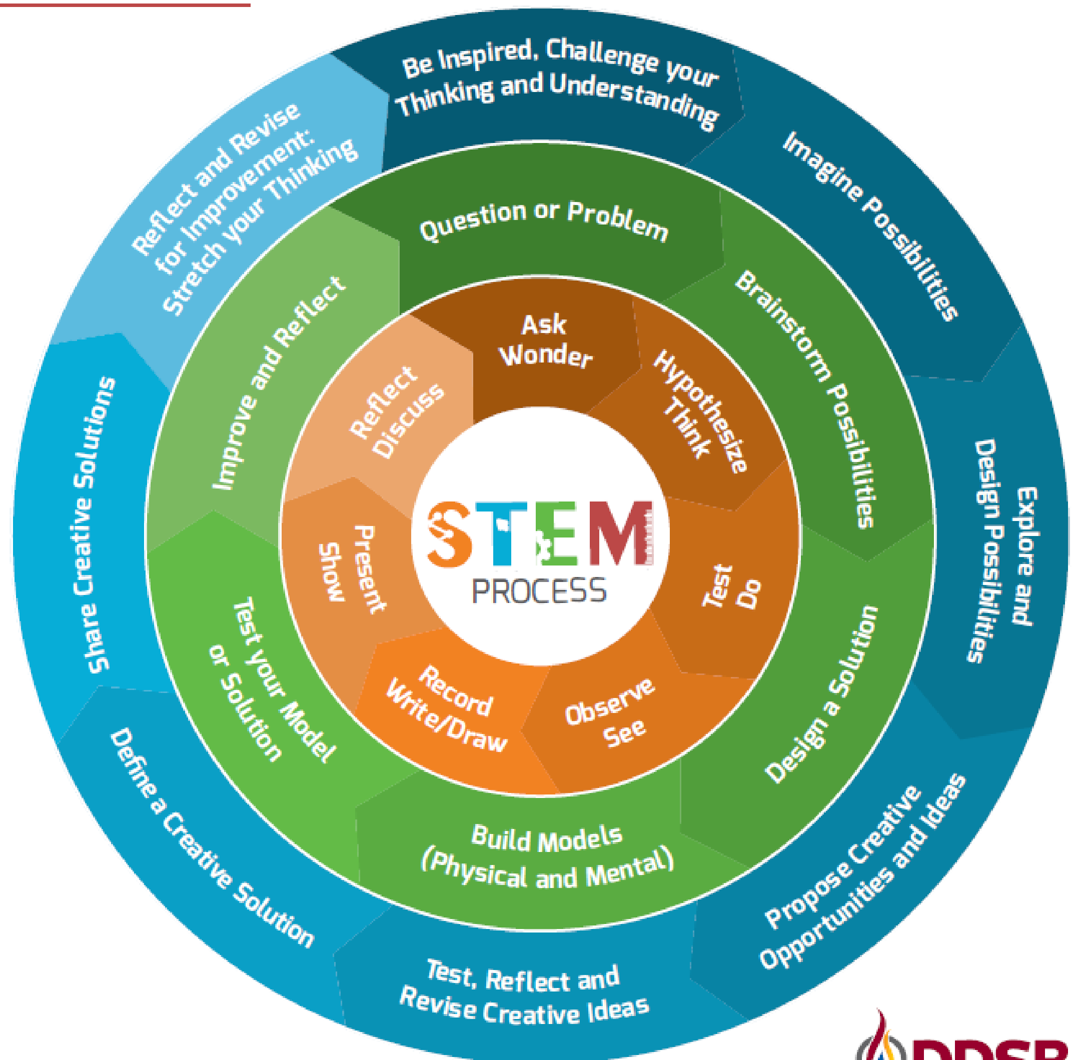
## STEM: Science, Technology, Engineering and Mathematics

STEM Education, an interdisciplinary approach for the curriculum disciplines of Science, Technology, Engineering and Mathematics, is a cohesive learning paradigm designed to support student learning as it relates to real-world applications. STEM Education promotes the development of essential 21st Century Skills and knowledge to best prepare students for the robust and evolving global society.

The School Effectiveness Framework (Ministry of Education) identifies innovation as an essential component of teaching and learning in the 21st Century classroom. STEM Education invites and reinforces students' creative thinking abilities, making innovation a cornerstone of the teaching and learning process.




science • technology • engineering • math



| Components of STEM | STAGE 1 | STAGE 2 | STAGE 3 |
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| **21st Century Skills Development**<br>Communication<br>Collaboration<br>Critical Thinking<br>Creativity and Innovation<br>Citizenship<br>Character<br>Digital Literacy<br>Entrepreneurship<br>Leadership<br>Adaptability | • Develop a plan that clearly connects the development of the 21st Century skills within the curriculum.<br>• Determine strategies for assessing 21st Century skills and providing ongoing feedback to students to support development.<br>• Create and implement assessment resources for effectively assessing 21st Century skill development. | • Ongoing review and reflection of assessment strategies and resources within a commitment of continuous improvement to build instructional efficacy<br>• Professional learning opportunities for educators will be designed to support 21st Century skills development in student learning. These opportunities will provide active learning experiences delivered within STEM-infused pedagogy. | • Effective assessment resources for 21st Century Skills development will be used regularly by students and teachers.<br>• Students and teachers will be engaged in a teaching and learning environment that values the development of 21st Century skills where student learning is differentiated to support individual student success for all.<br>• Students will become flexible thinkers and problem solvers as they learn together in collaborative spaces to build knowledge and explore possibilities in creative ways.<br>• Students will be encouraged to creatively apply a variety of resources they have gathered from their experiences. |
| **Pedagogy**<br>Inquiry based learning<br>(4 levels of inquiry - confirmation, structured, guided and open)<br>Project based learning<br>Cooperative Group Problem Solving<br>Rich Tasks<br>Experiential Learning<br>Learning through Games and Simulations<br>On-line Learning<br>Flipped Classroom | • Effective instructional strategies that support STEM-based learning are defined to promote exemplary practice and common language when discussing pedagogy.<br>• Each defined instructional strategy is further explored so that teachers have a deeper understanding of how each approach supports different elements of STEM Education implementation.<br>• STEM-based teaching and learning includes a diverse set of resources that teachers can use and draw from to suit the needs of their students.<br>• Develop a plan that scaffolds K-12 programming to ensure that students develop the skills necessary to make inquiry-based learning and cooperative group problem solving possible. Students will be provided with opportunities to revisit and build on skills regularly through a continuum of K-12. | • Continue to provide STEM-based professional learning that support educators with effective practices in teaching, learning and leadership.<br>• Professional learning opportunities will model effective lessons and leadership approaches to support a STEM-infused learning environment.<br>• Professional learning opportunities will take a job-embedded approach where educators are provided opportunities to engage in active learning experiences and apply their professional learning to their practice.<br>• Opportunities to co-create STEM learning resources and lessons with teams of teachers will be provided to further support professional learning. | • Educators are embedding a variety of pedagogical practices within the school and classroom that support student engagement for STEM-based learning.<br>• Students will develop 21st Century skills and apply them to solve complex problems in a fully integrated, interdisciplinary learning environment.<br>• Students are working collaboratively within the learning environment and the community to build knowledge using a variety of resources and approaches.<br>• Students are engaged in authentic, real world problems and experiences that emerge out of personal interest and wonderment. |
| **Assessment and Evaluation** | • Create and implement assessment resources for effectively assessing 21st Century skills development (collaboration, critical thinking, communication and creativity) in an inquiry-based learning environment.<br>• Design differentiated assessment and evaluation resources that align to identified instructional strategies (ex. inquiry-based learning, project-based learning, etc.). Resources will be implemented with ongoing reflection to allow for continuous improvement.<br>• Assessment and evaluation resources developed will be directly aligned to achievement charts outlined in Growing Success document.<br>• A variety of pre-, formative, and summative assessment methods are reviewed, designed and implemented.<br>• A variety of valid and reliable STEM-based data is consulted through the Assessment & Accountability department to provide a benchmark for continuously monitoring STEM implementation within the board. This data will also help inform next steps for STEM implementation. | • Ongoing development of assessment tools for 21st Century skills development (collaboration, critical thinking, communication and creativity) in an inquiry-based learning classroom.<br>• Ongoing creation of differentiated assessment and evaluation resources that align to identified instructional strategies (ex. inquiry-based learning, project-based learning).<br>• Implementation of assessment and evaluation resources will be continuously monitored to provide opportunities for ongoing revisions.<br>• Ongoing review, design and implementation of pre-formative, and summative assessment resources.<br>• STEM-based professional learning includes specific training on effective assessment and evaluation practices.<br>• STEM-based data is continuously monitored through the support of the Assessment & Accountability department to determine impact and inform next steps. | • Educators and students work collaboratively to place value on 21st Century skills development (communication, collaboration, critical thinking, creativity, citizenship, character).<br>• Educators and students work collaboratively to develop, use and reflect on assessment and evaluation practices through a transparent process.<br>• The Assessment Loop (as outlined in Growing Success) become common practice so that students are able to reflect on their own learning using a variety of strategies to self-assess their understanding. Furthermore, students are able to provide constructive feedback to their peers and work collaboratively to learn from their mistakes.<br>• Teachers are able to assess and evaluate student learning using a variety of tools that reflects the STEM classroom.<br>• STEM-based data is continuously monitored through the support of the Assessment & Accountability department to determine impact and inform next steps. |

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| **Innovation and Creativity** | **School Innovation:**<br>· Innovation in STEM Education will require schools to think about how STEM will be explored within the constraints of their own schools.<br>· A focus team of teachers, administrators and facilitators need to work together to develop a school specific vision.<br>· School Innovation that responds to STEM Education will challenge school teams to innovate new strategies to provide opportunities for interdisciplinary learning.<br><br>**Innovation Within the Classroom:**<br>· Innovation and creativity is critical in STEM Education. Students must be encouraged to explore how their own experiences and learning, obtained from all subject areas, can be used in integrated forms to wonder, ask questions, solve problems, create solutions and explore the universe.<br>· Students must be provided with opportunities to merge their learning and experiences within creative spaces that allows for student expression and student voice. Innovation is only possible when students learn to connect subjects and experiences together in creative ways. Opportunities for students to explore their own curiosities must be provided. | | |
| **Action Items** | · With support of the Assessment & Accountability Department, collect benchmark data on the current status of STEM Education in DDSB.<br>· Create focus teams of students, teachers, administrators, and parents to develop a clear vision and mission for STEM Education in DDSB.<br>· Identify STEM indicators/characteristics within a school/classroom/program and provide resources to support implementation at the school level.<br>· Design STEM assessment and evaluation resources that support successful implementation of STEM teaching and learning.<br>· Introduce professional learning opportunities for administrators and teachers to support STEM Education implementation. The professional learning will be provided by both internal and external opportunities so that special attention is provided for educators to learn and develop instructional skills and technical skills necessary to implement STEM Education.<br>· Through feedback and observation, identify the required training components for administration and teachers that will help shape future professional learning opportunities for STEM Education implementation at the elementary and secondary panel<br>· The DDSB Math Plan, 21st Century Classroom, and Ontario curriculum will be consulted to help create specific focus and alignment between Science and Mathematics content to provide the framework for STEM Education.<br>· Curriculum-based facilitators and coaches to be provided professional learning opportunities and training on STEM Education and technical STEM skills, with a strategic focus on how they can support implementation within their role.<br>· A central hub to collect, summarize, and share STEM resources amongst educators will be created through a Moodle page.<br>· Resources that bring awareness and provide career pathways for STEM careers will be developed and shared with secondary schools. The resources will also provide information on the essential "employability skills" that STEM employers place emphasis on.<br>· Provide ongoing responsive/differentiated support for STEM implementation at the school level. | · Ongoing data analysis through the support of the Assessment & Accountability Department to identify current status of STEM Education in DDSB and inform future STEM Education planning.<br>· STEM Steering Committee is created at the district level, with representation from various employee groups, to coordinate policies, procedures, and supports to help schools with effective implementation of STEM Education.<br>· STEM Teaching & Learning Teams are created to support the ongoing development of STEM-based resources. The teams would include a board-level facilitator team and school-based teams (including science, mathematics, and technology teachers) that are committed to ongoing professional learning and innovative teaching. STEM Teaching & Learning Teams work collaboratively to co-plan, co-create, co-implement, and co-revise STEM-based instructional and learning resources. STEM Teaching & Learning Teams are provided with professional learning and training to develop skills in facilitating and mentoring educators in the implementation of STEM.<br>· Ongoing STEM-based professional learning opportunities are provided that are responsive to educators at various implementation levels of STEM Education (these can range from the introductory level to a more fully-implemented level). The professional learning addresses both teaching and leadership practices so that a whole-school approach to STEM Education is supported. An active learning experience will be modelled within the professional learning to promote the essentials of STEM Education.<br>· STEM training will be made available for STEM teachers to develop technical skills that are necessary for STEM-based programs in schools.<br>· Through ongoing feedback and trends within board data on School District Reviews, identify the required training components for administration and teachers that require immediate attention for STEM implementation. This will help shape future professional learning opportunities to support STEM Education implementation at both the elementary and secondary panel.<br>· STEM Moodle page is supported and sustained as a collaboration vehicle for sharing STEM thinking and resources.<br>· Create partnerships with community, post-secondary institutions, and industry to further explore STEM opportunities and career pathways. Resources that support STEM career pathways will continue to be developed and provided to schools.<br>· Provide ongoing responsive/differentiated support for STEM Education at the school level. | · Ongoing data analysis through the support of the Assessment & Accountability Department to identify current status of STEM Education in DDSB and determine trends within the data. A culture of ongoing data analysis within STEM Education is established that informs future STEM Education planning.<br>· The STEM Steering Committee continues to assess, revise and make recommendations to further explore STEM Education in DDSB.<br>· STEM Teaching & Learning Teams continue to collaborate and explore creative opportunities for strengthening STEM Education across all school communities. Teams will be committed to the development of ongoing, responsive STEM resources. STEM Teaching & Learning Teams are provided with continuous professional learning and training to build STEM skills to effectively support schools.<br>· Ongoing STEM professional learning opportunities are provided that continue to be responsive to the unique needs of schools and educators. The professional learning will continue to be supported through a job-embedded approach.<br>· STEM training to develop technical skills necessary for STEM teaching and learning will continue to build sustainable STEM-based programs in schools.<br>· A culture of being responsive to the unique needs of schools is sustained so that professional learning opportunities are continuously evolving to meet the needs of all schools and the changing trends within STEM Education.<br>· A strong focus on interdisciplinary approaches to teaching and learning will emerge through STEM Education.<br>· A strong professional learning community will be developed where STEM resources and opportunities will be shared and discussed.<br>· Teachers will become facilitators, mentors, and co-learners within their classrooms where students are provided with opportunities to engage in their own learning.<br>· Review existing partnerships with the larger community, post-secondary institutions, and industry to further explore STEM opportunities and career pathways. Partnerships should look beyond simply a connection of individuals but focus on innovative ways to support STEM Education within the learning community. Resources that support STEM career pathways will continue to be developed and provided to schools.<br>· Provide ongoing responsive/differentiated support for STEM Education at the school level. |



DDSB
Ignite Learning

| Components of STEM | STAGE 1 | STAGE 2 | STAGE 3 |
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| **Science** | · Scope and sequence K-12 science curriculum document, with numeracy and literacy connections, is created and implemented to support school-based planning.<br>· Essential science skills K-12 continuum is designed and implemented to further support school-based planning with STEM implementation.<br>· Science programming is supported through professional learning opportunities that also address uniqueness of split-grade classrooms.<br>· Science resources are developed that model inquiry-based learning, cooperative group problem solving, project-based learning and rich tasks. Resources are strategically designed to scaffold learning of content, concepts, and essential skills for all students.<br>· A plan that outlines effective assessment and evaluation practices within STEM Education is developed with a specific focus on inquiry-based learning and essential STEM skills development.<br>· Knowledge building in classroom instruction is explored and professional learning is provided to support educators. | · Implementation strategies for improving STEM Education are further explored across all subject areas (within STEM and all other subjects) to move towards authentic STEM-based learning opportunities.<br>· Innovation is at the core of STEM Education where students learn to connect subjects and experiences together in creative ways.<br>· A common language for STEM Education is being used to develop and plan STEM initiatives within the DDSB learning community.<br>· STEM Steering Committee is created at the district level, with representation from various employee groups, to coordinate policies, procedures, and supports to help schools with effective implementation of STEM Education.<br>· STEM Teaching & Learning Teams are created to support the ongoing development of STEM-based resources. The teams would include a board-level facilitator team and school-based teams (including science, mathematics, and technology teachers) that are committed to ongoing professional learning and innovative teaching. STEM Teaching & Learning Teams work collaboratively to co-plan, co-create, co-implement, and co-revise STEM-based instructional and learning resources.<br>· STEM-based professional learning opportunities are responsive to educators at various implementation levels of STEM Education (these can range from the introductory level to a more fully-implemented level). The professional learning addresses both teaching and leadership practices so that a whole-school approach to STEM Education is supported. An active learning experience will be modelled within the professional learning to promote the essentials of STEM Education.<br>· STEM professional learning includes training opportunities to ensure that STEM educators are provided with opportunities to learn technical skills that are essential for STEM-based programs. | · Interdisciplinary teaching (across all subject areas) within a real-world context becomes regular practice as a core component of effective STEM Education. STEM Education provides opportunities for student discourse to solve authentic problems, propose solutions and contribute ideas to the larger community.<br>· Innovation is a transformational tool within the STEM learning community that naturally provides opportunities for students to take risks and explore endless opportunities.<br>· STEM Education is integrated within all aspects of the education and learning community.<br>· The STEM Steering Committee continues to assess, revise and make recommendations to further explore STEM Education in DDSB.<br>· STEM Teaching & Learning Teams continue to collaborate and explore creative opportunities for strengthening STEM Education across all school communities. Teams will be committed to the development of ongoing, responsive STEM resources.<br>· STEM professional learning opportunities will continue to be responsive to the unique needs of schools and educators. The professional learning will continue to be supported through a job-embedded approach.<br>· STEM training to develop STEM technical skills will continue to ensure that schools develop STEM program capacity and sustainability.<br>· All teachers, regardless of their teaching discipline, understand their role in STEM Education.<br>· Teachers engage in collaborative inquiry to support, develop, implement and open new opportunities for STEM Education.<br>· Students have opportunities in STEM Education to learn through inquiry in an integrated, interdisciplinary teaching approach.<br>· Students are able to use technology to explore, evaluate, investigate and design creative solutions to real-world problems. |
| **Technology** | · Software for PASCO and Vernier scientific probeware and hardware that support Science programming are supported (Grades 7 – 12) across the system.<br>· Technological resources that align to Science and Mathematics curriculum are summarized and annotated with specific uses to support educators with implementation.<br>· Technology-infused learning is embedded within STEM-based professional learning. This learning provides multiple opportunities to explore technology through a variety of domains (data analysis, coding, collaboration, augmented learning, etc.)<br>· Ongoing exploration of technology, both as a subject and a tool, to support STEM-based teaching and learning. Technology is both the high tech and low tech tools that can be used in developing STEM experiences for learning.<br>· Technology flexibility to enable higher-level thinking for robust application is supported within STEM-based learning. This provides students the opportunity to evaluate the purpose/strength of each technology and develop skills to be able to appropriately select tools for intended purpose.<br>· Digital Citizenship is foundational in supporting effective technology use.<br>· Multimedia literacy is explored both at the instructional and learning level to provide opportunities for students to share their learning using multimedia platforms. | | |

## Engineering

- The Engineering Design Process and Inquiry Process are explored and become integral in the creation of the Innovation and Creativity Cycle, which all work together to define the STEM process.
- Educators and students are provided opportunities to explore the engineering process in active learning experiences. The engineering process is always connected to a societal and environmental application.
- Ongoing active participation in partnerships with Engineers in Residence Program with Professional Engineers of Ontario, Engineering Change Lab through Engineers without Borders, and Faculties of Engineering to support STEM Education implementation.
- Professional Learning opportunities are provided that directly support the integration of the Engineering process within the STEM classroom (ex. WeMadeIt Resource for Grade 7-8 Science).
- Implementation of Robotics initiatives, both as curriculum-based programs and extra-curricular activities, are supported at the elementary and secondary level.
- Secondary course offerings for engineering-inspired courses (Engineering Design, Robotics, etc.) are developed and reviewed to determine next steps for greater student participation.
- Continuum of essential skills in Engineering from K-12 is designed to support teaching students to successfully engage in "building", "constructing", "creating a prototype", "designing", "coding", and "creative problem solving". Student learning is then extended to include skills in entrepreneurship (Engineering in industry).

## Math

- Analyze through comparison the scope and sequence for both the Mathematics and Science curriculum to identify connections.
- Develop integrated lessons between math and science to support interdisciplinary teaching and learning.
- Inquiry-based learning in Mathematics is supported and defined as an integral component of STEM-based learning.
- Instructional strategies to support implementation of inquiry-based learning, project-based learning and cooperative group problem solving in Mathematics are explored and support the development of STEM-based resources. Special attention is given to instructional scaffolding to promote deeper levels of student learning.
- Continuum of essential skills in Mathematics from K-12 is designed.
- Emphasis is placed on conceptual understanding in Mathematics so that specific attention is provided for students to learn mathematics with comprehension of mathematical concepts, actively building new knowledge from experiences and past knowledge.
- Mathematical discourse is defined and supported within professional learning as anchor to the application of mathematical thinking when solving complex real world problems. (ex. data analysis, interpretation of data, and relationships between concepts, transferability of skills in a wide variety of situations)
- STEM Education is informed and directly aligned to the DDSB Math Plan.

- STEM Education becomes embedded within School Improvement Planning and the School Self-Assessment process. The School Effectiveness Officer supports STEM Education through the District Review Process and ongoing collaboration with School Improvement Team leaders.

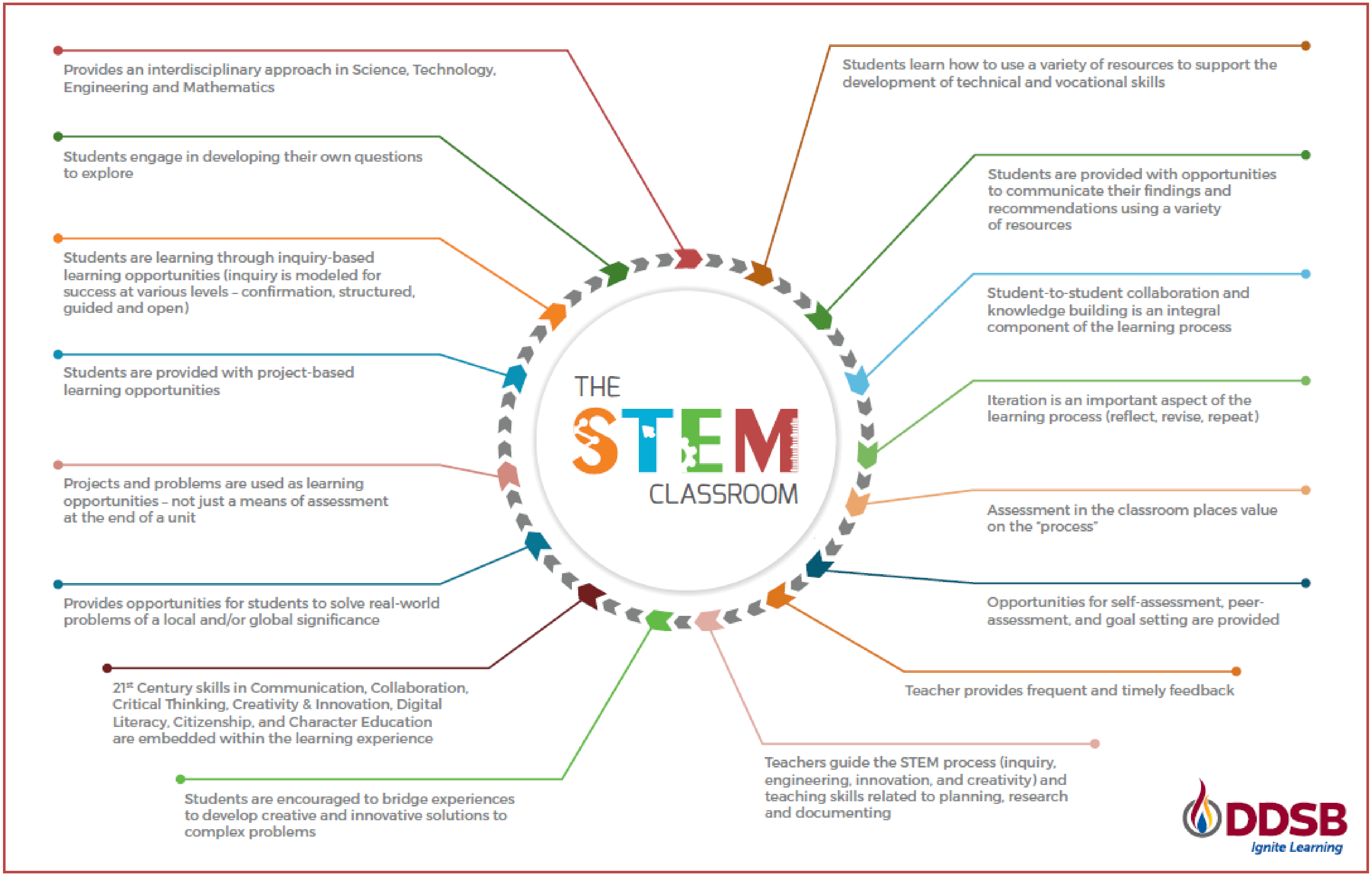
- Create partnerships with community, post-secondary institutions, and industry to further explore STEM opportunities and all career pathways (workplace, college, and university).

- 21st Skills (collaboration, communication, critical thinking, creativity, citizenship and character) development is provided within all learning opportunities.

- STEM Education is an integral component of School Improvement Planning and the School Self-Assessment process. The School Effectiveness Officer supports STEM Education through the District Review Process and ongoing collaboration with School Improvement Team leaders.

- Review existing partnerships with the larger community, post-secondary institutions, and industry to further explore STEM opportunities and career pathways (workplace, college, and university). Partnerships should look beyond simply a connection of individuals but focus on innovative ways to support STEM Education within the learning community.

- Seek out new opportunities for partnerships in STEM Education.


THE STEM CLASSROOM
Provides an interdisciplinary approach in Science, Technology, Engineering and Mathematics
Students engage in developing their own questions to explore
Students are learning through inquiry-based learning opportunities (inquiry is modeled for success at various levels – confirmation, structured, guided and open)
Students are provided with project-based learning opportunities
Projects and problems are used as learning opportunities – not just a means of assessment at the end of a unit
Provides opportunities for students to solve real-world problems of a local and/or global significance
21st Century skills in Communication, Collaboration, Critical Thinking, Creativity & Innovation, Digital Literacy, Citizenship, and Character Education are embedded within the learning experience
Students are encouraged to bridge experiences to develop creative and innovative solutions to complex problems
Students learn how to use a variety of resources to support the development of technical and vocational skills
Students are provided with opportunities to communicate their findings and recommendations using a variety of resources
Student-to-student collaboration and knowledge building is an integral component of the learning process
Iteration is an important aspect of the learning process (reflect, revise, repeat)
Assessment in the classroom places value on the "process"
Opportunities for self-assessment, peer-assessment, and goal setting are provided
Teacher provides frequent and timely feedback
Teachers guide the STEM process (inquiry, engineering, innovation, and creativity) and teaching skills related to planning, research and documenting
DDSB Ignite Learning