STEM Education: A Pathway to Developing Twenty-First Century Leadership and Career Skills

by

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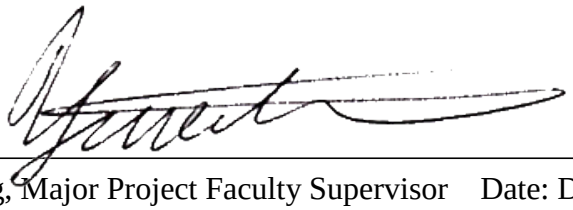

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Abstract

Literature in the field suggests that a disconnect exists between the way we teach in 2016, and the twenty-first century skills and competencies students need to succeed in our rapidly changing, technologically-driven, interconnected world. It appears that STEM education, which builds upon problem-based learning, project-based learning, inquiry, and social learning, aligns well with the twenty-first century skills students need for today's workforce – particularly the leadership skills students need to bring about change. Therefore, this project's critical question asks: How can STEM education be a pathway to developing twenty-first century leadership and career skills? To answer this question, the *Architects of Change: STEM Leadership* website was developed. The website's activities, such as an Extreme Environments Unit and other STEM lessons, were created to align with the Grade 6 BC Ministry of Education curriculum. The *Change from Within* Leadership Development approach (created for this project and integrated into lessons) presents the notion of working from "the inside out," developing intrapersonal domain skills as a means to then develop interpersonal domain skills, which are necessary for success in today's society. Activities, lessons, templates, and resources were designed and presented for two levels of leadership development and inquiry. Feedback solicited from a group of education students, through written and scaled responses, suggested that the majority of respondents felt the website's activities met the project's primary goal of fostering leadership development through STEM education.

Major Project url: https://sites.google.com/site/leadersviastem/home

Keywords: student leadership, twenty-first century skills and competencies, STEM education

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Thank you to Dr. Alec Couros and #ETMOOC for starting this educational journey! Now, upon completion, I would like to offer my sincere gratitude to my MEDL supervisor, Avi Luxenburg, and the Vancouver Island University faculty who were always so inspiring and supportive. Avi, you managed to challenge me and bring out the best in me, even when I doubted my abilities. I would also like to thank Mary O'Neill, Coordinator and Instructor of the OLTD Graduate Diploma Program, for her unwavering dedication to her students.

The past few years have been difficult, and the loss of my mother to cancer, combined with the loss of a job I loved in the field of online learning, nearly ended this educational pursuit. However, with change comes opportunity, and as my mother taught me, there are always alternate routes to meet one's goals and avenues of interest. Therefore, I would like to dedicate the completion of this master's project to my late mother, Margaret Redway, who inspired my love of learning and passion for science (and yes, many 'experiments' in the family garage). My mother's keen interest in science led to her contribution towards the *Science Safety Resource Manual*, released by the Curriculum Development Branch of the BC Science Ministry (https://www.bced.gov.bc.ca/irp/resdocs/scisafe/moescisaf.pdf). This document was subsequently distributed to all High Schools in BC, and it marked the beginning of an increased awareness in schools with regard to science safety. Thus, my mother taught me the importance of science safety, but more importantly, she taught me to question, to experiment, and to try, try, try again. She would have loved to see me reach this milestone in my learning. Finally, I would like to thank my daughter, Janna, for her continued love, encouragement, inspiration, and daily text messages. My deepest thanks also go to my father, Brian Redway, for encouraging his girls to always be strong. The support by those around us makes anything possible!

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Chapter 1 – Introduction

Purpose of the Major Project

The purpose of this project was to assess ways in which STEM education can contribute towards the acquisition of student leadership skills and competencies, based on the Grade 6 BC Ministry of Education curriculum. Although the research presented literature on STEM education and leadership at the professional level (i.e., Buckner & Boyd, 2015; Elrod & Kezar, 2014; Elrod & Kezar, 2015; Elrod & Lester, 2011; Merrill & Daugherty (Eds.), 2010), few articles addressed ways in which STEM education encourages leadership among students. In fact, Hine (2014) stated, "Student leadership and student leadership development… is a critical issue worth investigating due to its dynamic nature and implications for the future, as well as to the striking dearth of literature associated with this subject" (p. 79). In partnering the competencies of leadership and collaboration, the BC Ministry of Education (2015) suggested that leadership is a twenty-first century competency that students need "to succeed" (p. 4). Other publications, such as the landmark OECD survey and working paper (Ananiadou & Caro, 2009), outlined more specifically the need for leadership skills and competencies for success in the twenty-first century workforce. Therefore, it is proposed that by empowering students to take control of their learning and become leaders, they broaden their opportunities and create change – for themselves, for others, and for society. All students are potential leaders; educators just need to pave the way. This master's project addressed the question of how leadership can be developed using an integrated approach to learning.

Justification of the Major Project

As an educator who embraces technology, and one who loves to innovate and test new or emerging technologies and pedagogies, this author believes that subject areas and activities that

develop twenty-first century leadership and career skills must be highlighted and emphasized in today's rapidly changing world. Technology, despite its ability to provide 24/7 access to knowledge, social and professional networks, and an increased efficiency in workflow and productivity (among a number of other things), is only a tool and a means of meeting one's needs. It is our ability to make a difference, and our understanding of human character traits and twenty-first century skills, that will foster success and sustainability in this global, interconnected world.

The Adaptable Mind film by The Moxie Institute (Shlain & Steele, 2015) powerfully illustrates skills needed to succeed in the twenty-first century. The diminishing need for skills such as memorization and the ability to perform routine tasks are counterbalanced and outweighed by the increasing need for skills such as curiosity, creativity (i.e., how you are able to connect ideas in new ways), initiative (i.e., knowing when to reach out to people), multi-disciplinary thinking (i.e., STEM – Science, Technology, Engineering, and Math), and empathy (i.e., sensing the motives and feelings of others). These "human character" skills have become increasingly important, and as stated by Shlain & Steele (2015), "Empathy is at the core of our ability to communicate, to work together, to be a part of our rapidly changing world" (n.p.). Society has moved from an agricultural economy to an industrial economy (where importance shifted to production and manufacturing), and from a knowledge economy (where value was placed on data and information) to a *human economy* (a shift occurring at present, where value is placed on "human" traits). This has led educators to ask the question: Are we preparing our students for the future by helping them develop these all-important human skills? Have our schools and teaching models or philosophies changed to match the human economy?

Although models, philosophies, and theories of teaching and learning have evolved over time to better reflect the current pedagogies (methods and practices of teaching) and realities of our twenty-first century learners, this is an ever-evolving process. The behaviourist perspective of B.F. Skinner (McLeod, 2015), which utilizes positive reinforcement and conditioning by providing frequent feedback on activities, worked well for the *what* questions (i.e., questions requiring factual/content-related answers). However, the cognitive constructivist perspective, attributed to Piaget (1952), advocates for learning based on individual activity and fits new experiences with existing mental frameworks. These frameworks are then modified for new results and build on the learner's understandings to answer the *how* and *why* questions. The social constructivist approach, largely attributed to Vygotsky (1962), recognizes that activity and interaction with others are also important for building understanding. Yet, as an article by Donaldson (2014) stated, there is a position that bears attention in today's interconnected world: "Papert (who developed the theory of constructionism) […] felt that Piaget's constructivism placed too much emphasis on the internal mental processes of learners. Papert insisted that learning occurs […] through constructing real-world inventions which can be shared with others" (n.p.).

Despite support for Papert's philosophies of teaching and learning, a disconnect has appeared between how schools teach and how students learn (Dweck, 2015; Richardson, 2015). Will Richardson (2015), during his TEDxWestVancouverED talk entitled *The Surprising Truth About Learning in Schools*, outlined the need to: "1) Articulate and share personal beliefs about how students learn best, 2) Come together as a school to create principles of what we think learning looks like in our schools, and 3) Align our practice to our beliefs so we can see learning happen in our classrooms" (n.p.). Richardson (2015) observed that in this time of "abundant

access" (to people, information, apps, etc.), deep and powerful learning requires students to be genuinely and personally interested in the topic. Yet, many of the structures, systems, methodologies, and practices (i.e., standardized testing, students learning the same subject material, emphasis on grades, sitting in rows or adhering to a set time/block schedule, etc.) that occur within schools work against productive learning. As noted by Richardson (2015), for deep and productive learning to occur, students require conditions such as a safe and positive environment, personal investment, real world application, challenge, relevance to the students' lives, a real audience, autonomy and agency, and flexibility of time. Dweck's research on motivation and mindset support these precursors for deep and powerful learning. As stated by Dweck (2014, 2015), in a *fixed mindset* the belief is that intelligence is fixed, but in a *growth mindset* the belief is that abilities can be developed through hard work and dedication, where the focus is on the process of learning.

Daniel Pink (2011) in *The Surprising Truth About What Motivates Us*, offered a similar view to that of Richardson and Dweck about learning and motivation. Pink noted that individuals inherently want/need three things to engage in meaningful learning: autonomy (individuals want to be in control – if you want engagement, self-direction is better), mastery (individuals naturally want to improve performance and attain skills), and purpose (individuals want to belong to something greater than themselves; they want what they do to have meaning or purpose). Therefore, as educators, can we provide students with the opportunity to fulfill these inherent needs (of autonomy, mastery, and purpose) so they may experience deep and powerful learning? Can we offer students the opportunity to make a difference through student-directed and student-centric learning opportunities? Considering the relevance of Papert's constructionist philosophy of learning in today's technologically driven and networked world, a pedagogy rich in twenty-

first century outcomes needs to drive what educators do in the classroom (i.e., the experiences offered to students, and the models of teaching used). An education that provides ample opportunity for leadership development through engagement in meaningful inquiry – through a Science, Technology, Engineering, and Math (STEM) focus – could benefit and prepare learners of the twenty-first century.

Critical Question

This project examined the following question: **How can STEM education be a pathway to developing twenty-first century leadership and career skills?** This question is important because our modern world will be reliant on a workforce of citizens who have the ability to collaborate, problem-solve, and demonstrate leadership through the uncertainty of change.

Definition of Terms

Please refer to Table 1 for definitions to assist in understanding the scope and purpose of this project.

Brief Overview of the Major Project

To support and address this project's critical question, theoretical models outlined in the Chapter 2 Literature Review were used as a foundation to design learning opportunities to develop leadership skills and competencies via STEM education. A website was developed, and activities and assignments were created and linked to an Extreme Environments Unit (addressing the content competencies of Science, Mathematics, Applied Design Skills and Technologies, Arts Education, Language Arts, and Career Education). Activities supported the development of leadership competencies addressed in the Chapter 2 Literature Review, including those outlined by the BC Ministry of Education (2015). The activities and assignments were posted for other

educators to freely use, and resources on extreme environments were also posted for students to access. It is hoped that this project's website may be useful for others interested in STEM education and student leadership. The student-centric pedagogical approach to leadership development used throughout this project, over time, should be extended to the school and community, so the projects' goal of students being positive contributing citizens, who are able to demonstrate leadership through action, is meaningful and realized in the real-world context. It is expected that modification of lesson plans, etc. (due to learning from practice and feedback from others), will lead to better design, and more importantly, to an increased acquisition level of skills and competencies deemed important for happy, productive, empathetic, and ethical global citizens and student leaders…leaders of change… and responsible stewards of the Earth.

Chapter 2 – Literature Review

Introduction

It can be said that the Internet now connects us like neurons in a giant brain: an interconnectedness and interdependence exists, and educators have been tasked with the crucial role of helping twenty-first century learners gain a set of skills and competencies they will need to succeed in our interconnected and digital world (BC Ministry of Education, 2015). As Stephen Hawkings (2011) stated, "Our population and our use of the finite resources of planet Earth are growing exponentially, along with our technical ability to change the environment for good or ill" (n.p.). Kamran Walsh (2016), an intern of *Education First's* (EF) *Global Student Leaders Summit*, stated, "We live in an era characterized by material excess and overconsumption, especially when concerning energy usage…[and] as one would imagine this does not bode well for the longevity and health of our environment" (n.p., para. 2). The goal of each EF summit is to empower students of today to start becoming leaders of tomorrow (Walsh, 2016, n.p.) – leaders equipped with the skills needed to manage and sustain their environments.

Learners of the twenty-first century must possess specific knowledge and skills to develop leadership in their roles as global citizens and stewards of our environment, and to navigate and thrive in our rapidly changing world (BC Ministry of Education, 2015). Given the immense technological advancement we see in society today, and given the requirements for a workforce inundated with information daily, it seems like an education intertwined with Science, Technology, Engineering, and Mathematics (STEM) may foster many of the required skills and competencies students need to succeed (Buckner & Boyd, 2015; Council of Canadian Academies, 2015; DeCoito, 2014; Johnson, Adams Becker, Estrada, & Freeman, 2015). The purposeful integration of STEM education, which at its heart builds upon problem-based

learning, project-based learning, inquiry, and social learning (to address real-world problems), aligns well with the required twenty-first century skills – particularly leadership skills and competencies.

Twenty-First Century Education: Skills and Competencies

The term *Twenty-First Century Education*, under which *Twenty-First Century Skills and Competencies* fall, has been widely used for years; however, some have reported that no single framework describes the required knowledge, attitudes, skills, and values – the competencies (Ananiadou & Claro, 2009; Pellegrino & Hilton, 2013; Marope, 2014). Yet, P21 Partnership for 21st Century Learning (2016) would perhaps challenge this notion, as they have outlined a *Framework for 21st Century Learning*, which describes:

> the skills, knowledge and expertise students must master to succeed in work and life; it is a blend of content knowledge, specific skills, expertise, and literacies…When combining the entire Framework with the necessary support systems – standards, assessments, curriculum and instruction, professional development and learning environments – students are more engaged in the learning process and graduate better prepared to thrive in today's global economy. (P21 Partnership for 21st Century Learning, 2015, n.p.)

The P21 Framework is comprised of four key elements: 1) Key Subjects and Twenty-First Century Themes; 2) Learning and Innovation Skills; 3) Information, Media and Technology Skills; and 4) Life and Career Skills. It is under Life and Career Skills that the sub-elements of Leadership and Responsibility fall. It should be noted that one of the strengths of the P21 Framework is the inclusion of "Twenty-First Century Support Systems" (P21 Partnership for 21st Century Learning, 2016, n.p.). This recognizes the need for a holistic approach to learning that

includes support systems to ensure that the students' learning experiences build twenty-first century skills and competencies.

Silva (2009), as cited by Marope (2014), noted the term "twenty-first century skills" may reflect a shift in emphasis, rather than a new set of skills. This shift has resulted from new challenges such as the rapid pace of technological change, concerns for environmental sustainability due to increased resource extraction, a recognition of a digital and economic divide, and, in Canada, an aging population (Council of Canadian Academies, 2015). Marope (2014) stated that twenty-first century education needs critical and creative thinking, problem-solving, Information and Communication Technology (ICT) skills, and the ability to apply this set of skills to problems and real-life contexts (p. 484).

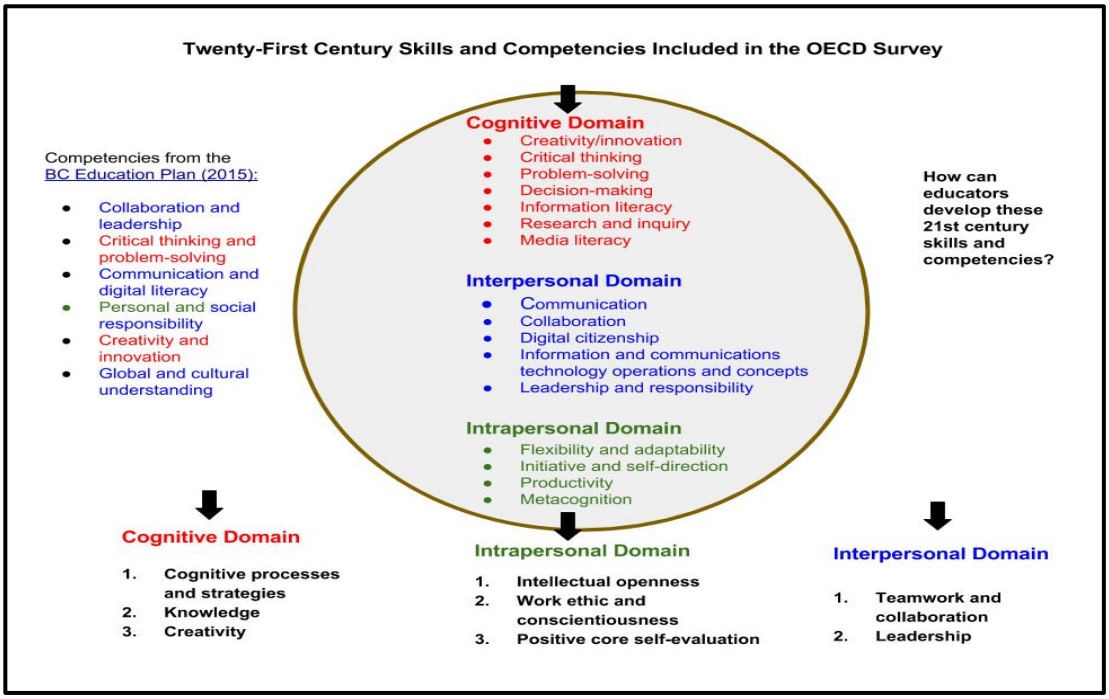

*Figure 1***.** Twenty-First Century Skills and Competencies Included in the OECD Survey. Adapted from "21st Century Skills and Competences for New Millennium Learners in OECD Countries," by K. Ananiadou and M. Claro, 2009, *OECD Education Working Papers, No. 41*, p. 20-21. OECD Publishing.

A list of twenty-first century skills and competencies, drawn from the landmark OECD survey and working paper (Ananiadou & Claro, 2009), has been adapted for this project and is illustrated in Figure 1. The skills and competencies are divided into three domains: the cognitive, the intrapersonal, and the interpersonal. Under each domain, a cluster of competencies has been highlighted. The value in addressing the various domains should be noted and deemed an appropriate match for a holistic STEM approach. However, from these domains, the fundamental skill set needed for the twenty-first century remains a topic of much debate.

Life and Career Fundamental Skills and Competencies

In this networked, technologically data-driven world, it has become increasingly important to have a fundamental skill set… a skill set to navigate and access services and employment, and to allow for equal opportunity for social and economic success (Perlmutter et al., 2010; Warschauer & Matuchniak, 2010). The Media Awareness Network (now MediaSmart), in their submission to the Digital Economy Strategy Consultation on Digital Literacy in Canada (Perlmutter et al., 2010), outlined that basic human rights such as equal access to information, health care, government services, and the ability to participate in a digital economy can be limited by a lack of skills (and technologies and/or bandwidth) to navigate online services and resources. Meanwhile, the Conference Board of Canada (2016) has outlined a set of basic skills needed for gaining and maintaining employment. These skills include: *fundamental skills* (the ability to communicate, manage information, use numbers, think and solve problems), *personal management skills* (the ability to demonstrate positive attitudes and behaviours, be responsible, be adaptable, learn continuously, work safely), and *teamwork skills* (the ability to work with others and participate in projects and tasks). Yet, as the Council of Canadian Academies (2015) stated, “There is uncertainty about precisely which skills are needed [for a successful life and

career in the twenty-first century]...and whether there is an optimal combination of skills that fosters growth" (p. xii).

In an effort to address the growing importance of life and career skills and competencies, the BC Education Plan (BC Ministry of Education, 2015) outlined the need for innovative teaching, personalized learning, and an opportunity for students to apply their knowledge in a real-world setting. The BC Ministry of Education's (2013) Draft*: Defining Cross-Curricular Competencies – Transforming Curriculum and Assessment* outlined a set of three cross-curricular competencies considered to be necessary: thinking ("encompasses critical, creative, and reflective thinking, represents the cognitive abilities that students develop through their studies"), personal and social ("represents the personal, social and cultural abilities that students develop as individuals and members of society"), and communication ("represents the abilities students need to interact and learn effectively in their world") (p. 3). This author would also suggest that leadership competencies should be included among the cross-curricular competencies needed for twenty-first century learners to succeed. As noted by the Government of Canada (2007), key leadership competencies could include: values and ethics (integrity and respect), strategic thinking (innovating through analysis and ideas), engagement (joint concerns and collaboration), and management (action, people, or financial). For elementary school students, however, further assessment of the term leadership is needed to arrive at a meaningful definition for the twenty-first century. Leadership is a role for all, and as such, the individual's context will in all likelihood influence the skills and competencies associated with this term.

Leadership

A Role for All. Although early theorists believed leaders were born with innate leadership skills and qualities, the scientific study of leadership has evolved, and leadership models of the

twenty-first century continue to be defined (Hess, 2010). A variety of leadership models have emerged over the years, and the twenty-first century has seen the adoption of a collaborative approach to leadership. This model – termed the Social Change Model of Leadership Development by the Higher Education Research Institute (Astin & Astin, 1996; Hess, 2010) – outlined, just prior to the twenty-first century, that co-curricular experiences could create "powerful opportunities for leadership development through collaborative group projects that serve the institution or the community" (Astin & Astin, 1996, p. 16). This supports the notion that STEM education, which fosters project-based learning and collaboration, can be a pathway to developing twenty-first century leadership skills. As Astin and Astin (1996, p. 16) state:

> A leader is not necessarily a person who holds some formal position or is perceived as a leader by others. Instead, a leader is one who is able to affect change which helps others, the community, and society. Any individual is a potential leader. The process of leadership involves collaborative relationships that lead to collaborative action, affecting change. (As cited by Hess, 2010, p. 13)

Elrod & Kezar's leadership definition, built upon Kezar and Lester's (2011), similarly notes the ability of a leader to bring about change: "Leadership is an effort by groups or individuals to create change, where leadership is distinguished from management (although not always separate) and not necessarily synonymous with authority" (2014, p. 34). Elrod & Kezar (2014) further note that in order to lead, a shift in mindset, from "me" (individual goals and actions) to "we" (collective goals and collaborative work), needs to occur. This point is pivotal to this paper's guiding question, which asks: How can STEM education be a pathway to developing twenty-first century leadership and career skills? Perhaps a look at theoretical models of teaching and learning can help to answer this question.

Theoretical Models

STEM integration within the classroom, school, and community can be an excellent vector to stimulate a change in mindset, from "me" to "we," in order to develop leadership capacity within students. Elrod & Kezar (2014) suggested the integration of STEM subjects are ideally suited to incorporate a collaborative model of learning (an aspect important to the building of leadership skills) such as Kolb's Experiential Learning Cycle (Kolb, Boyatzis, & Mainemelis, 2001). Kolb's model of learning integrates situated cognition (a theory which posits that knowing and doing are inseparable), social interaction, authentic activities, and a transfer of skills to the real world, through hands-on, experiential, collaborative, and personally meaningful learning experiences.

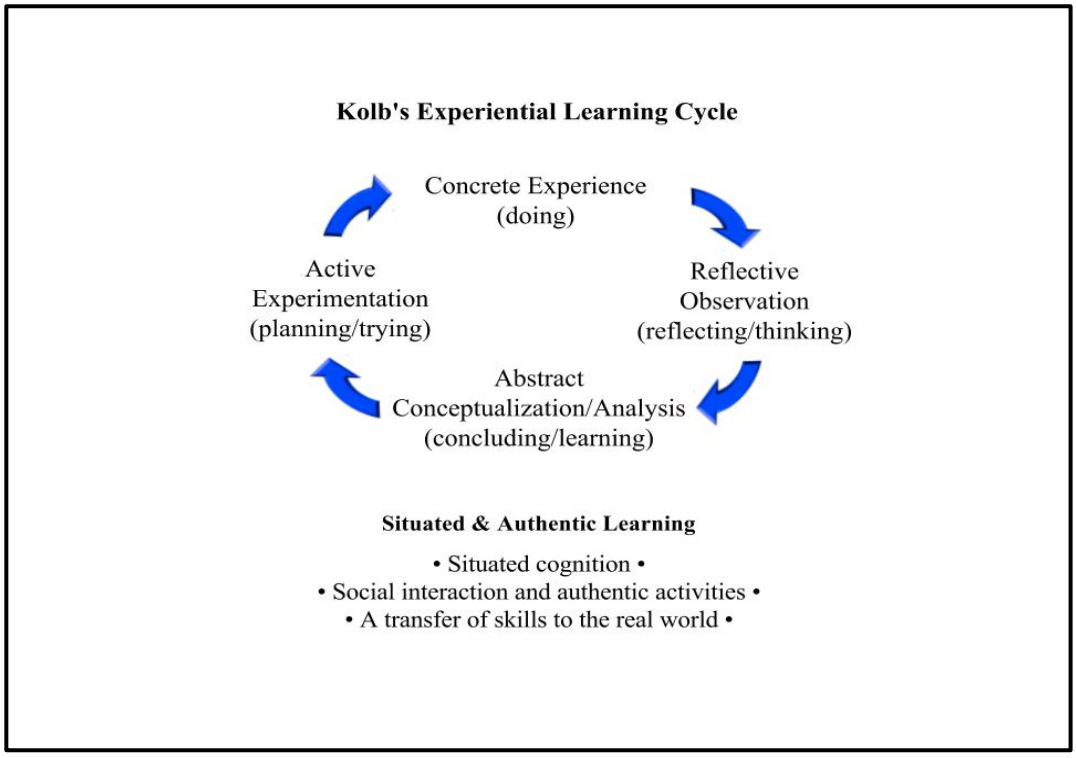

Figure 2. The Four Stages of Kolb's Experiential Learning Cycle. Adapted from "Experiential learning theory: Previous research and new directions," by D. A. Kolb, R. E. Boyatzis, and C. Mainemelis, 2001, *Perspectives on thinking, learning, and cognitive styles*, *1*, 227-247.

As outlined by Elrod & Kezar (2014), and as illustrated in Figure 2, Kolb's model of learning is a cycle that begins with a concrete experience or an event in which the learner actively participates. The learner then reflects on the experience, so he/she can expand on the experience and identify what he/she learned. The cycle is then completed when the learner transfers his/her newly acquired skills to real-world situations via active experimentation. Meanwhile, the Community of Inquiry (CoI) theoretical framework (illustrated in Figure 3),

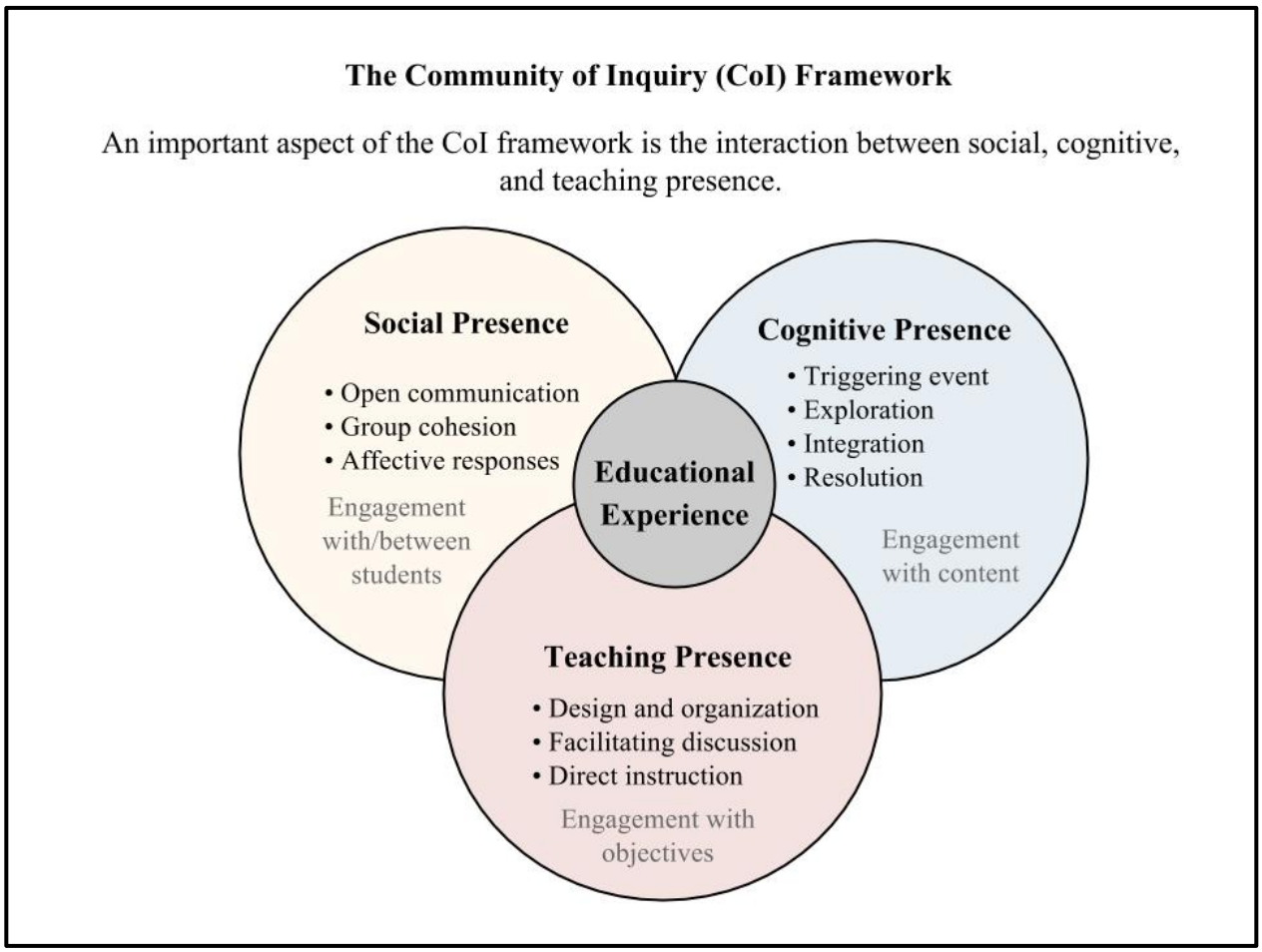

Figure 3. The Community of Inquiry (CoI) Framework. Adapted from *CoI. The Community of Inquiry*, by R. Garrison, M. Cleveland-Innes, and N. Vaughan, n.d. Retrieved from http://coi.athabascau.ca/.

which represents a collaborative-constructivist learning experience developed through three interdependent elements (cognitive, social and teaching presence), posits that students learn best within a diverse and supportive community (Garrison, Cleveland-Innes, & Vaughan, n.d.). As suggested by Elrod & Kezar (2014, p. 34 and 36), these two theoretical models – the CoI framework and Kolb's Experiential Learning Cycle – are a good fit for building leadership in STEM fields.

Regardless of the theoretical model(s) chosen for STEM implementation, the Government of Canada noted, in *Key Leadership Competencies* (2007), that leadership should be built upon a foundation of values and ethics. Leadership competencies need to be highlighted because of their direct relationship with other skills and competencies, such as those deemed important by the BC Ministry of Education (2015), including collaboration, critical thinking and problem-solving, communication and digital literacy, personal and social responsibility, creativity and innovation, and global and cultural understanding. Consequently, leadership skills and competencies also partner well with the theoretical models, methodologies and outcomes of STEM education.

STEM Education

What is STEM? STEM, coined by the National Science Foundation (DeCoito, 2014), is the intermixing of: **S**cience – the study of the natural world, **T**echnology – "any product made by humans to meet a want or need" (Jolly, 2014, n.p.), **E**ngineering – the design process used to solve problems, and **M**athematics – the language of shapes, numbers, and quantities. However, STEM is not just a grouping of subject areas, but it is their "intersection" and a holistic approach to solving problems (DeCoito, 2014; Jolly, 2014). It is also a concerted movement by the public and private sectors to develop the scientific and mathematical principles students need to be successful in the twenty-first century workforce. Yet, the STEM movement far exceeds the goal

of preparing students for jobs. A major goal of STEM is to improve STEM proficiency for all students, regardless of their interest to pursue STEM as a career or field of study (DeCoito, 2014, p. 34). “STEM skills have been advanced as central to innovation and productivity growth, which are in turn necessary for improving standards of living” (Council of Canadian Academies, 2015, p. vi). STEM develops a set of skills that can be used in all areas of daily life, such as reasoning, problem-solving, critical thinking, creative and investigative skills, self-directed learning, technological literacy, teamwork and collaboration, to name a few. Therefore, STEM education is a way to deliberately incorporate a variety of subjects into an integrated curriculum (as one would experience in the real-world).

STEM and Beyond. It should be noted that there is now a trend to move from STEM, or STEM+, to STEAM or SHTEAM (Science, Technology, Engineering, Arts and Humanities, and Mathematics), or even CSTEM (Communications, Science, Technology, Engineering, and Mathematics), as these movements allow for a more multi-disciplinary approach. For example, STEAM and SHTEAM include the arts and humanities activities, which are also important skills for a twenty-first century workforce (Johnson et al., 2015, p. 6 and p. 18; Shlain & Steele, 2015, n.p.). Similarly, CSTEM includes communications, although some might argue that communications can be interwoven throughout the other subject areas, and through the development of leadership and human skills such as empathy (Shlain & Steele, 2015). It is this author’s view that the arts and humanities are naturally interwoven throughout STEM subjects, to varying degrees (i.e., the engineering design process requires an element of art, while math displays art through symmetry and geometric shapes, etc.), and the inquiry process itself often relates to solving cultural problems or aspects of the human condition. For the remainder of this project, research and analysis will highlight STEM, to allow for a more focused investigation of

the project's critical challenge inquiry question with regard to the development of leadership and career skills.

Why is STEM Education Important? STEM education plays an important role, not only at the K-12 level but also at the post-secondary level (Elrod & Kezar, 2015). As cited by DeCoito (2014), a report by the Conference Board of Canada on education and skills in Canada identified that Canada seems to be slipping with regard to STEM graduates at the post-secondary level (STEM graduates in 2010 accounted for 21.2% of overall graduates – the third year of decline). Similar findings were reported by the Council of Canadian Academies (2015), as noted in a graph of StatCan data from 2001-2011 (p. 105, Figure 6). DeCoito (2014) suggested the decline in STEM graduates is reflected in the decreased employment of graduates in STEM fields and could be one of many contributors to Canada's poor innovation and productivity record (p. 35). Yet, "Complementary skills, such as communication, teamwork, and leadership, are also important in and of themselves, as well as to maximize the impact of STEM skills" (Council of Canadian Academies, 2015, p. xv).

Although post-secondary STEM graduates are not a primary goal for STEM education, or for this project, the topic should be addressed, because it presents another persuasive argument for the implementation of STEM education at the early grade levels. STEM is more than just a subject area; it is an ideal way to demonstrate leadership through thinking about and solving real-world problems. With a dwindling number of STEM graduates, Canada needs to rely on other countries for a labour force to fill STEM positions, and in turn, to consequently solve Canadian STEM-related problems (whether they be environmental, technological, health-related, etc.). "Many jobs are going unfilled simply for the lack of people with the right skill sets" (Buckner & Boyd, B, 2015, p. 19). More importantly, this means Canada is limited in its ability to lead the

way and procure contracts in areas related to STEM exploration and innovation, thus affecting productivity (Council of Canadian Academies, 2015). The importance of STEM education for Canada's contribution to the global market was another reason to focus this literature review on the benefits that STEM education affords when introduced at the K-12 grade level (and specifically at the elementary school level). Although this project looked at STEM education in the early years, and its potential for developing leadership and future career skills and competencies, the inherent nature of STEM education to promote interest and engagement in real-world ventures (potentially leading to increased STEM engagement at the post-secondary level and beyond) should be noted as an important outcome of early STEM education (DeCoito, 2014).

The Importance of STEM at the K-12 Grade Level. Much of the literature on STEM education has pointed to the foundational role that elementary Math and Science education plays in contributing towards the direction a student may take in later grades, and in their careers. Although the Council of Canadian Academies (2015) noted there is "a clear link between the role of early mathematical skills and the later acquisition of knowledge in a variety of fields", such as later STEM skill building, it is also noted that, "To build capacity and maximize Canada's potential for innovation, evidence points to the value of early childhood interventions to strengthen fundamental skills" (p. 85 and xiv).

Unfortunately, an underrepresentation of STEM in schools has contributed towards poor engagement and enthusiasm in elementary science education (DeCoito, 2014; Tasar, 2007). Yet, support for STEM education and positive attitudes are highly important. The lack of engagement and interest in the STEM areas in earlier grades not only limits course options available in higher grades and employment options beyond (due to a lack of foundational knowledge and/or pre-

requisite courses), but it also limits the opportunities students have to contribute to change, both in their lives and in the world (DeCoito, 2014, p. 35). Through STEM education, if implemented with careful attention to appropriate learning design models, students are better able to solve real-world issues and problems (Buckner & Boyd, 2015). Students can learn the engineering design process, where they identify and define a problem, conduct research, develop multiple ideas for solutions, and arrive at one idea for which they design a prototype. They can then test the prototype, reflect on and evaluate the design, and redesign it to make improvements (Jolly, 2014, n.p.). Through this process, students can learn many social, collaborative, teamwork, and leadership skills. Students can learn to undertake open-ended exploration and hands-on inquiry, making this a natural part of their learning, and most importantly, they can engage in deeper learning, to develop a growth mindset where "failure" is considered a positive step towards discovering and designing solutions (Dweck, 2014; Jolly, 2014).

Transfer of Knowledge and Skills via Domains of Learning/STEM Pedagogies. It is believed that in order for the transfer of knowledge and skills to occur, *deeper learning* first needs to take place. Pellegrino & Hilton (2013) referred to deeper learning as, "The process through which an individual becomes capable of taking what was learned in one situation and applying it to a new situation (i.e., transfer)" (p. 5). Furthermore, Fullan and Donnelly (2013) noted that digital learning contributes to deeper learning, and they stated that twenty-first century learning skills fall into three domains: "1) the cognitive domain (thinking); 2) the intrapersonal domain (personal skills of drive and responsibility); and 3) the interpersonal domain (teamwork and other relational skills)" (p. 11). Figure 1 categorizes twenty-first century skills and competencies under the three domains (adapted from Ananiadou & Claro, 2009; Pellegrino & Hilton (Eds.), 2013), and it also notes skills and competencies identified by the BC Education

Plan (2015). The challenge lies in designing a STEM implementation plan to bring about deeper learning and the transfer of knowledge and skills from these domains (specifically with regard to leadership and career skills and competencies).

STEM pedagogical methodologies are ideally suited to promote deeper learning and the transfer of knowledge and skills. Project-based learning, problem-based learning, and inquiry-based learning are examples of pedagogical methodologies that foster more active learning experiences. These experiences offer students the opportunity to brainstorm and implement solutions to local and global problems, therefore, applying learning to a real-world context. The goal of deeper learning "is to assess a student's performance through more than just a test score" (Johnson, Adams Becker, Estrada, & Freeman, 2015, p. 10) – the application of learning can be demonstrated through projects, interactions, self-assessment, and other formative assessment methods. Furthermore, project-based learning and inquiry-based learning have been reported to be particularly well-suited to address gaps in science education, while project-based learning has also been documented to work for a wide range of students, regardless of sex, ethnicity, and socio-economic background (Johnson et al., 2015, p. 10). Shared learning experiences, such as those afforded by the aforementioned active learning methodologies, offer an opportunity for deeper learning to occur as a result of *productive struggle*. Dweck (2014) reported that by pushing out of our comfort zone and trying new and challenging things, our brains form new connections. These new neural connections help to make us "smarter" over time, as intelligence is not fixed; neural connections can be formed and deepened (Dweck, 2014, n.p.). Thus, through deeper learning, expertise is developed in a domain of knowledge or performance. This knowledge, including content knowledge and the ability to discern when, why, and how to apply this knowledge, is referred to as a *twenty-first century competency* – a blend of knowledge and

skills. Therefore, the way in which the learners (and their class/groups and community) structure, organize, integrate, and apply the knowledge and skills, supports transfer of these increasingly important skills and competencies.

An Implementation Plan

Plan for Success: Develop a Framework. In a pre-publication draft, *Increasing Student Success in STEM: A Guide to Systemic Institutional Change,* Elrod & Kezar (2015) outlined that before a change is made, it is important to 1) establish the vision and goals for a change project, and 2) complete a preliminary analysis phase to gather data and collect information about student success in STEM learning. The analysis phase identifies challenges, from which desired outcomes are developed. The outcomes for the proposed change project then direct the formulation of strategies and an implementation plan, which can be evaluated for its success. Yet, for STEM implementation to be successful, a number of variables should be considered.

As outlined by Honey, Pearson, & Schweingruber (2014), many variables could be incorporated into a framework for STEM education. As many as 100 “critical components” may be important to a school’s success; however, Honey et al.’s (2014) framework consists of four main components to provide a simplified, higher-level conceptualization of an integrated STEM education (p. 32). The four components noted are: goals (for the students, such as STEM literacy, twenty-first century competencies, etc., and for the teacher, such as increased STEM content knowledge, increased pedagogical content knowledge), outcomes (for the students and teacher directly related to the chosen goals), nature and scope of integration (such as the type of STEM connections, disciplinary emphasis, duration, size and complexity of initiative), and implementation (instructional design, educator supports, learning environment adjustments).

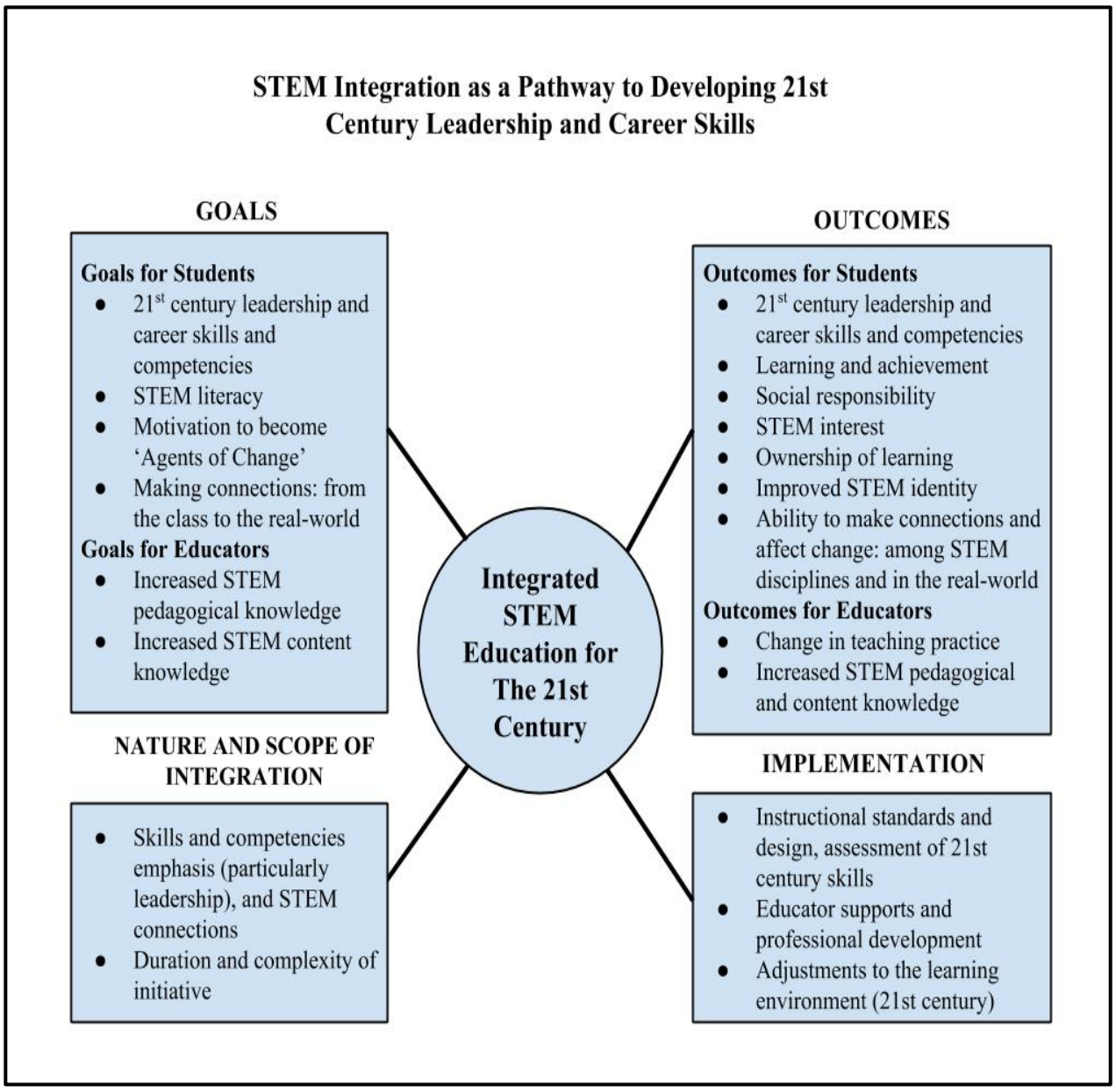

Figure 4. STEM Integration as a Pathway to Developing Twenty-First Century Leadership and Career Skills (a descriptive framework). Adapted and reprinted from *STEM integration in K-12 education: Status, prospects, and an agenda for research,* (p. 32), by M. Honey, G. Pearson, and H. Schweingruber, (Eds.), 2014, Washington, DC: National Academy of Sciences. Copyright 2014 by National Academy of Sciences. Adapted and reprinted with permission.

The Integration of STEM: A Complex Task. Literature indicates that the integration of STEM education in a manner that reflects the true essence of STEM is a more complex task than just addressing teacher training. Studies indicate that student success in Mathematics and Science is positively related to the teacher's subject knowledge (Council of Canadian Academies, 2015, p. 93). However, Tasar (2007), in his review of the book *Taking Science to School: Learning and Teaching Science in Grades K-8,* reinforced the notion that teaching Science requires not just good subject knowledge, but also good pedagogical knowledge, and an understanding of how to "do" science, and thus the practice of science, itself. "Many teachers suffer from limited understandings of what scientists do" (Tasar, 2007, p. 164). DeCoito (2014) also commented that while integrating STEM subjects can be engaging and can contribute towards many of the STEM competencies and learning outcomes (i.e., problem-solving, critical thinking, making real-world connections), this can often be problematic for educators. While educators may have the content knowledge of the individual subjects, and while they may see many conceptual links between the given domains of knowledge, without an understanding of the process of science, educators often struggle to meaningfully integrate the teaching of the STEM subjects in an effective and fluid manner (p. 35). However, the achievement of student success through the implementation of STEM education requires more than just improvements in pedagogy and curriculum. It requires a multifaceted change that includes professional development for teachers, teacher and student mentoring opportunities, external partnerships (to bridge the gap between academic knowledge and concrete applications), and a school or district-wide approach (Elrod & Kezar, 2015).

Teachers/Leaders as "Change Agents". An article in the *Journal of Leadership Studies* by Elrod & Kezar (2014) outlined the importance of leadership within the STEM fields, not only to implement successful STEM education but to model leadership and develop more leaders

through the process. The term *change agent* is used to describe the role of teachers or leaders who focus on leading reform; reform, in this case, based on pedagogies that promote student engagement (Elrod & Kezar, 2014, p. 34). Fullan & Donnelly (2013) stated it is important for the teacher to be a change agent as opposed to a facilitator. With the change agent role, the teacher is an *activator* – i.e., the teachers and students are both teachers learning from each other, and students are in charge of their own learning. The teacher and student make the thinking process explicit, and they challenge goals by setting ambitious but achievable goals. However, the achievement of these goals requires a classroom environment in which pedagogical change can be nurtured and supported.

The Classroom Environment. An examination of the shift to deeper learning approaches has suggested that a *Classroom Community of Inquiry* is a good model to demonstrate leadership skills and show students how to respect the opinions of others (Johnson et al., 2015, p. 10). This model, which is well suited for STEM education, should encourage the use of technologies to facilitate and engage in communication and expression. Educators who engage in professional development to improve their own inquiry skills are often more successful at formulating a classroom community of inquiry (Johnson et al., 2015). This community of inquiry should encourage students to be actively engaged in thought-provoking activities, while alternative modes of problem-solving are also valued and promoted. Johnson et al. (2015) noted the importance of implementing proper strategies for learning activities, such as clear expectations and instructions, small groups, and close supervision and support of learners (p. 12). Marope (2014), meanwhile, noted that educators need to have a holistic approach to teaching and learning so that assessment systems match the goals of curriculum design and development.

Feedback should be useable and there should be a de-emphasis of memorization and an emphasis on reflection, collaboration, and peer-instruction (Brandywine School District, n.d.).

Classroom culture can be described best by those who are immersed in the classroom culture itself: the teachers and students. The Brandywine School District (n.d.), as articulated on their STEM website (http://www.brandywineschools.org/Page/48), arrived at some descriptors for what a STEM-friendly classroom should be like. Their "STEM Philosophy" webpage, based on research from "The National Science Education Standards (NRC, 1996), the National Council of Teachers of Mathematics Standards (NCTM 1989 and 2000); the National Education Technology Standards for Students (ISTE, 1998, 2007); and the Standards for Technological Literacy (ITEA, 2007)" (Brandywine School District, n.d., n.p.), summarized that:

> The culture of a STEM-friendly classroom should be open to new ideas, and encourage curiosity, creativity, and healthy questioning. Meanwhile, informed skepticism should be welcomed, dogmatism should be avoided, and ethical decisions should be considered. There should be a diminished fear of risk-taking, and mistakes should be seen as learning opportunities. The classroom culture should value clear expression and communication, promote a detailed awareness of systems, and exploration should precede formal presentation (i.e., to class, school, community). (Brandywine School District, n.d., n.p.)

Thus, the culture created within the classroom should provide a supportive environment for a classroom community of inquiry, and the culture should extend beyond the walls of the classroom to permeate into the school and community.

The School Climate. The school climate, which reflects values, norms, goals, organizational structures, interpersonal relationships, and the teaching and learning practices that exist within a school, can influence the success of STEM education. Organizational structures

that are flexible allow more time for professional learning and collaboration among teachers, leading to more innovative learning approaches (Johnson et al., 2015, p. 12-13). Traditional bell schedules, however, symbolize the separation of disciplines and thus discourage the creative application of technology (Johnson et al., 2015). Furthermore, the interdisciplinary learning and integrated studies associated with STEM education appear to be antithetical to traditional methods of organization and structure. Thus, "As learning becomes more fluid and student-centred, some teachers and administrators believe that schedules should be more flexible to allow opportunities for authentic learning and ample room for independent study" (Johnson et al., 2015, p. 8).

Finally, the importance of parental involvement should be noted as a positive contributor towards school climate. A STEM education and leadership program (Federal Mathematics and Science Partnership program, Illinois State University), reviewed by Merrill & Daugherty (Eds.) (2010), reported that due to parents having a significant impact on student achievement, successful approaches to STEM education and leadership tend to also involve parents in their professional development efforts (p. 7). It is anticipated, therefore, that with parental involvement (i.e., with projects and classroom/school/community activities), and through ongoing communication (regarding goals, activities, and desired outcomes), the implementation of STEM education should be more successful. The holistic approach to teaching and learning, when implementing STEM education as a pathway to developing twenty-first century leadership and career skills, appears to be pivotal.

Assessment. A good example of a holistic approach, which has led to systemic change, has been seen in Finland where alternative methods of evaluation are used prior to the fifth grade (i.e., projects, portfolios, self-assessment, and other qualitative and formative assessment

methods). Alternative methods have been adopted as a representation and assessment of knowledge acquisition, as opposed to grades (Johnson et al., 2015, p. 7). Johnson et al. (2015) commented that traditional assessment methods (such as tests) do not encourage the creative application of technology. The authors question traditional modes of summative assessment that evaluate mastery with regard to accuracy, test scores, and other straightforward measures. Interestingly enough, despite creativity being widely identified as an important outcome of schooling, and despite this outcome being one of the twenty-first century competencies sought by employers (Figure 1) and seen as a "social good" (Lucas, Claxton, & Spencer, 2013, p. 9), "The lack of school-friendly tools to assess creativity is arguably another reason for paying less attention to creativity than to content or procedure knowledge" (Lucas, Claxton, & Spencer, 2013, p. 9). The *OECD Education Working Paper, No. 86* (Lucas et al., 2013) suggested practical ways to develop and track creativity in schools (for example, see the *OECD Education Working Paper* Appendix 1: Field Trial 2 - Assessment 2). Thus, as educators, it is important to create a toolbox of formative and summative assessment tools and methods that are well suited to evaluate or assess the desired STEM learning outcomes – i.e., assessment tools for twenty-first century skills and competencies. Examples of assessment templates and rubrics may be found on the accompanying website for this master's project (Appendices A-Q).

Conclusions and Suggestions for Change

Given the uncertainty of our future with regard to our natural and man-made worlds, one of the best ways we can prepare our students to be flexible, adaptable, and successful is to ensure they have a strong fundamental skill set. Fundamental skills such as those outlined in the BC Education Plan (2015) – collaboration and leadership, critical thinking and problem-solving, communication and digital literacy, personal and social responsibility, creativity and innovation,

global and cultural understanding – can be fostered through STEM education and are vitally important for success in a variety of education and career paths. Yet, although the cognitive and interpersonal domains are often well represented in educational plans, this author suggests that competencies and skills should be more clearly defined from the intrapersonal domain. The BC Education Plan (2015) specifies personal responsibility as an important skill, but perhaps competencies such as flexibility, adaptability, initiative, self-direction, productivity and metacognition are also important skills to include on this list. Furthermore, perhaps leadership skills and competencies, built on a strong foundation of values and ethics, could be a way to connect and represent other career skills and competencies (and indeed STEM literacy). These leadership, career, and STEM competencies and skills are vital for twenty-first century employment and success.

To ensure success in the twenty-first century, a proactive and strategic approach should provide individuals with the flexibility to pursue a variety of opportunities. A focus on STEM education in the younger grades should develop a "STEM-literate society" with a strong set of twenty-first century fundamental skills, which in turn could improve Canada's poor innovation record and offer individuals a strong economic future (DeCoito, 2014, p. 35). Yet, to truly engage and inspire students within the STEM areas at the elementary grades, teachers should be offered opportunities to participate in professional development and professional learning networks. Educators have a role to play in promoting favourable attitudes towards STEM. However, many factors contribute towards the acquisition of attitudes and skills, and economic drivers can sometimes impact the attainment of these fundamental skills and competencies by students. It is generally felt that personalized learning is not adequately supported by current technology (its availability and/or acceptance) or methodologies and practices (Johnson, Brown,

Cummins, & Estrada, 2012, p. 3). Could it be that we do not fully highlight the need for certain skills and competencies in our current education plans because perhaps we do not know how to assess or represent them? The question should be: How can we change our educational environments and practices to build more opportunity for a brighter future for our students by using STEM education as a pathway to developing twenty-first century leadership skills and competencies… and, therefore, success?

To answer this project's critical question, research outlined in the literature review was incorporated into the build of this project's deliverable component: The *Architects of Change: STEM Leadership* website. Pedagogies and theories of learning that promote engagement and inquiry were foundational for the development of student activities. For example, the Community of Inquiry (CoI) theoretical framework, due to its collaborative-constructivist approach, was integrated into the development of activities; this approach to learning is well suited to STEM education. Through the development of three interdependent elements (social, cognitive, and teaching presence), social learning and the co-construction of ideas and meaning can occur, and so too can deep and powerful learning (Garrison et al., n.d.). Furthermore, aspects of Kolb's learning cycle were also incorporated into website activities. Reflective observation (one of four stages in Kolb's cycle of experiential learning), and the use of authentic activities and situated learning promote the transfer of skills to real-world applications (Brown, Collins, & Duguid, 1989; Kolb et al., 2001). As noted by Papert & Harel (1991), learning happens best when learners tinker, explore and construct understanding through building real-world inventions to share with others (the theory of constructionism).

Finally, student activities on the *Architects of Change: STEM Leadership* website were designed with a focus on twenty-first century skills and competencies, particularly those skills

deemed important for leadership development. Skills and competencies noted by Ananiadou & Claro (2009) and the BC Ministry of Education (2015), illustrated in Figure 1, were the foundation for developing this project's student leadership development approach (the *Change from Within* Leadership Development approach). Furthermore, the Descriptive Framework by Honey et al. (2014) identified the importance of goals and outcomes for both students and educators when integrating STEM education (p. 32). An increased STEM pedagogical and content knowledge and a change in teaching practice were noted to be important goals for educators when incorporating STEM education. Therefore, the *Architects of Change: STEM Leadership* website's information, activities, resources, and rubrics/templates have been posted and shared as an open educational resource. It is hoped the website will be useful for others interested in STEM education and leadership, and at the same time further this author's professional development. Feedback on the website's resources will help to answer the critical question: How can STEM education be a pathway to developing twenty-first century leadership and career skills?

Chapter 3 – Procedures and Methods

Introduction: Leadership from the Inside Out!

To conceptualize the development of student leadership, a framework was created, and website activities were designed to reflect the *Change from Within* Leadership Development approach.

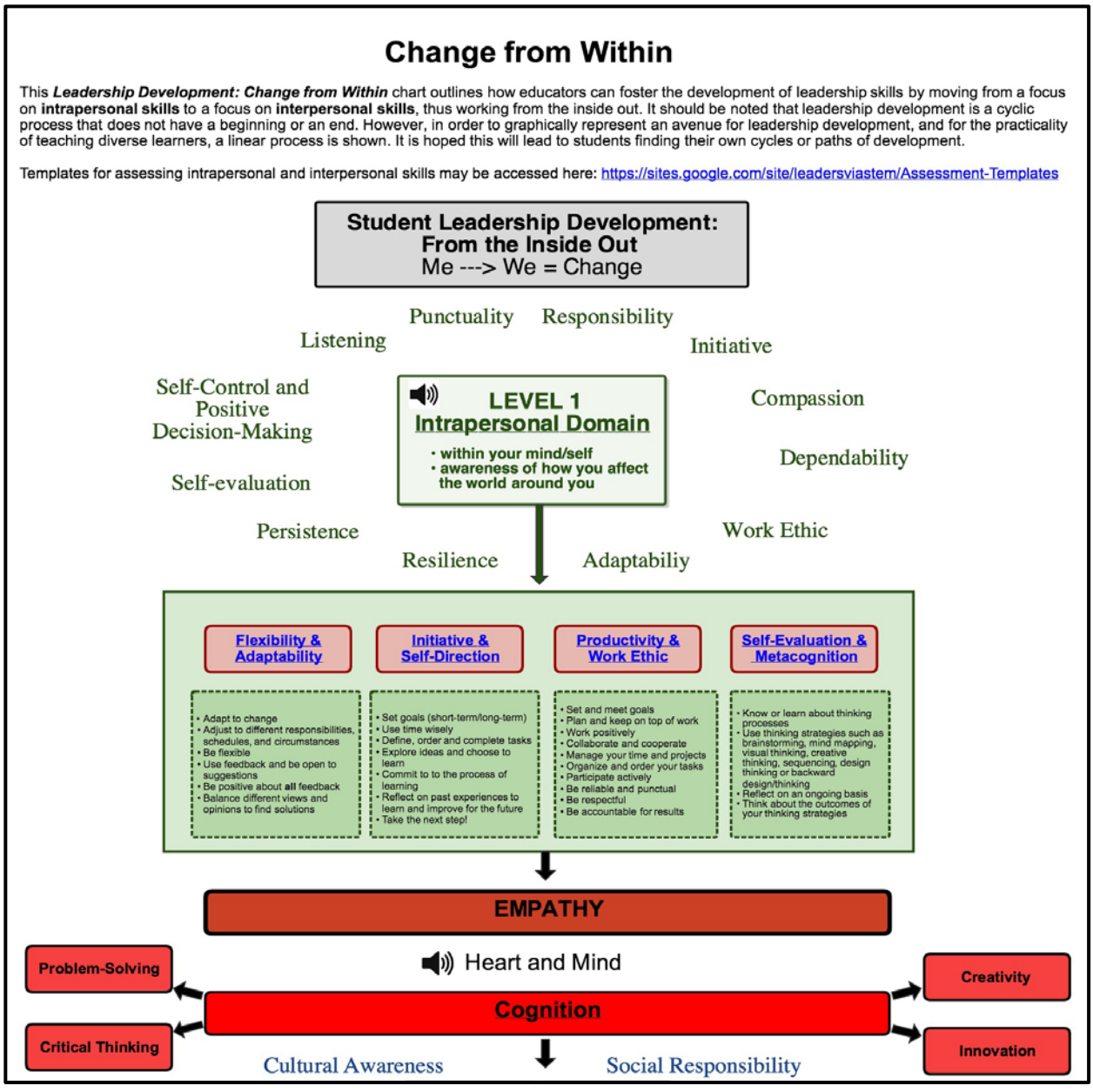

Figure 5A. A chart of the *Change from Within* Leadership Development approach (Part A)

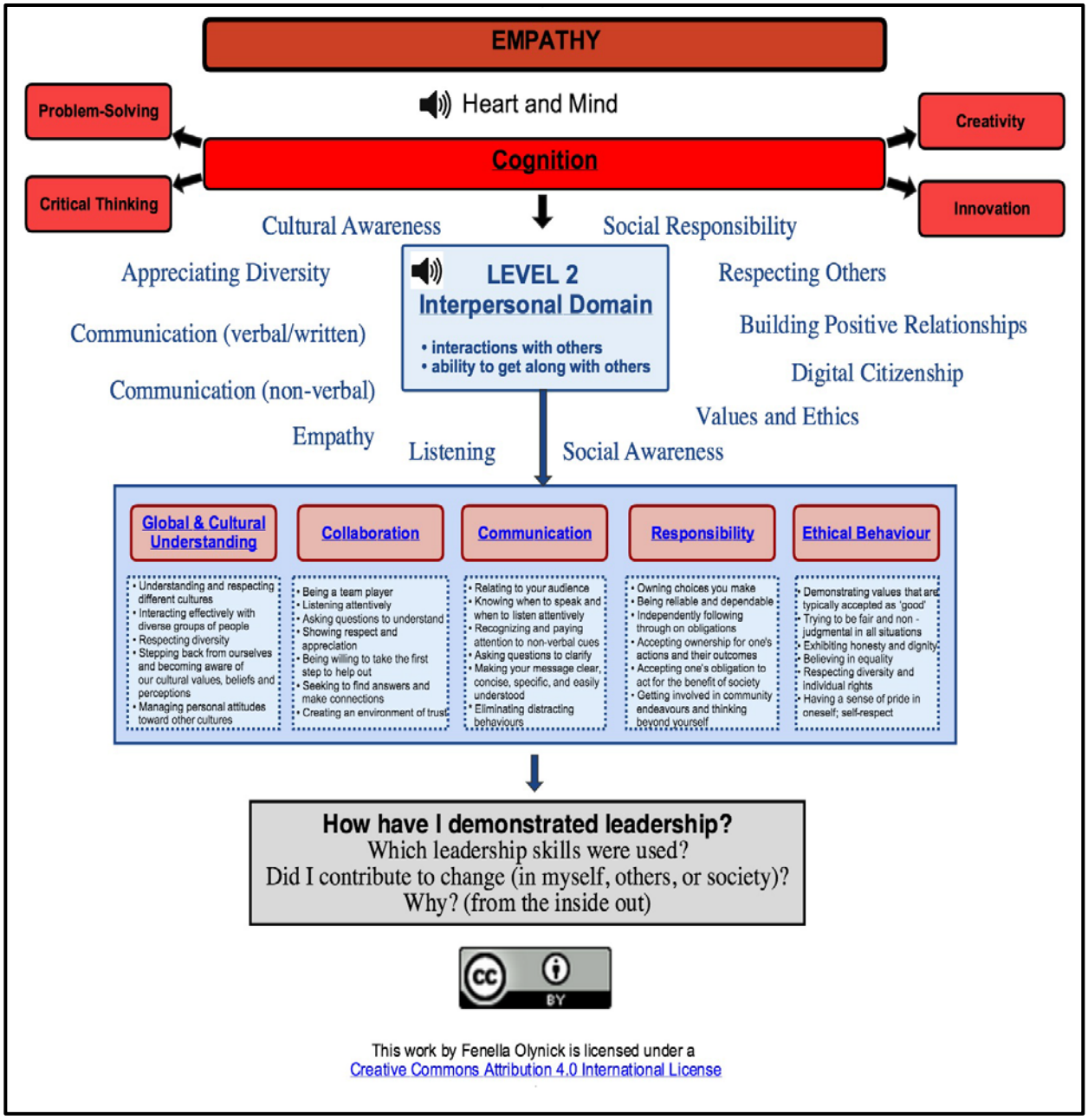

Figure 5B. A chart of the *Change from Within* Leadership Development approach (Part B)

The *Change from Within* Leadership Development approach, created by this author, evolved from theory and research conducted during the Chapter 2 Literature Review. As a

necessary component of this approach (in order to answer the critical question of whether STEM education can be a pathway to developing leadership and career skills), activities on the *Architects of Change: STEM Leadership* website were designed with a focus on inquiry and/or a collaborative-constructivist approach to learning. The Community of Inquiry Framework, Kolb's Learning Cycle, Papert's constructionist theory of learning, and the *Change From Within* Leadership Development Framework were used as models for the development of website activities.

Throughout the development of website activities, and as suggested in the *Journal of Leadership Studies* (Elrod & Kezar, 2014), a shift in mindset, from "me" (individual goals and actions) to "we" (collective goals and collaborative work), was incorporated. This was illustrated on the *Change from Within* Leadership Development Chart. The chart was created to show the order of activities and a visual representation of leadership development. The website's activities were divided into two levels of inquiry: Level 1 and Level 2.

Inquiry Level 1 not only introduced students to content knowledge (i.e., related to extreme environments), but it also focused on fundamental intrapersonal skills. Intrapersonal skills relate to a person's ability to reflect on and monitor his/her own emotions, and to understand and have an awareness of how he/she can affect the world around him/her. These skills are the foundation for developing the leadership and career skills necessary for succeeding in our twenty-first century workforce. *Inquiry Level 2* guided students towards more advanced research and inquiry (i.e., for project development). Students were provided with an opportunity to further develop leadership and career competencies. A higher degree of cooperation and collaboration was required, thus developing the interpersonal skills necessary for success in today's workforce. The website was designed to include activities to encourage students to first of all define, examine

and assess their intrapersonal skills, and to then practise using the *Level 1 Skills* through STEM lessons and activities. Next, the website included activities and resources to encourage students to define, examine and assess their interpersonal skills, and to then practise using the *Level 2 Skills* through more complex and interactive STEM lessons and activities. The development of these leadership skills was designed to work towards participation in a school STEM Fair (similar to a Science Fair, but designed to highlight the integration of STEM subjects). A STEM Fair would provide students with the opportunity to become real architects of change (using the STEM Fair as a springboard for change), and to interact with members of the school and community – once again working from the inside out – to create change… in self, in others, and in society.

Major Project Design

The Timeline. To assist in working towards meeting this project's critical challenge question, a timeline was developed to keep the project on track. The timeline identified the following stages: *Planning and Project Proposal* (July, 2016), *Project Development and Build* (August), I*mplementation of STEM Leadership Development Activities* - Grade 6 (September/October 2016), and *Completion of Project Including Plans for a STEM Fair* (November/December 2016) (Appendix R). The calendar, created using a *Google Spreadsheet*, was divided by the month into weekly intervals, and progress points for each stage were identified accordingly. Creating this project timeline proved to be very valuable as a visual organizer.

The Goals. The main goal of this project was to answer the critical challenge question: How can STEM education be a pathway to developing twenty-first century leadership and career skills? The project was also designed with two subordinate goals:

1. The ability to share activity ideas, assessment templates, lesson materials, etc., and to seek feedback on these resources (from educators and others);
2. An easily navigable platform that other educators might deem worthy enough to use – i.e., to download templates and printable resources, or to modify and adapt resources to meet their needs and the needs of their students.

For this reason, it was decided that the deliverable component of this project would be the *Architects of Change: STEM Leadership* website. After considering *WordPress*, *Weebly*, and *Google Sites* as potential platforms to house the project, *Google Sites* was chosen as the platform, primarily due to the ease of sharing materials and resource pages. The project's website highlighted activities designed to develop student leadership skills through STEM education, and assessment templates were created and aligned with these goals.

Major Project Development and Delivery

The development of the project's website was a continually evolving process; the structure, appearance, and content of the deliverable (the website) morphed and changed throughout the development stages. The website went through several iterations of layout and design. In the beginning, it was hoped that a layout might be created that could be easily viewed on all devices. This proved to be a bit of a design challenge due to a few *Google Sites* limitations. As with any communications interface, change will continue to occur as needed, and based on feedback.

The *Architects of Change: STEM Leadership* website was created with a space theme so that the visual appearance of the website would fit with content contained within its pages. Meanwhile, the horizontal navigation bar was designed with a tab for the *Home* page, and the layout of the Home page was visually simple and uncluttered to avoid any confusion about where to start. "Start Here" images with links were used to link to the next page(s) in the

navigation menu, which for educators was a *Site Map* and for students was an *Extreme Environments Resource* page. The Site Map, as outlined by Vancouver Island University Instructor and Master's Supervisor, Avi Luxenburg, can be a useful website component, as it helps to ensure the successful navigation of a website (A. Luxenburg, personal communication, August 19, 2016). This project's Site Map was designed to provide a simple flowchart to navigate to other areas of the website. Website content areas, identified on the flowchart by outlined boxes, were hyperlinked to further levels of website content. These content areas were also included in the horizontal navigation bar. Horizontal navigation tabs were labelled to include: *Architects of Change* (under which Student Leadership information was placed), *STEM* (leading to coding and robotics information, and the like), *Resources* (leading to information on Extreme Environments), *Activities/Assignments, Templates/Rubrics, Bibliography*, and *Feedback/Contact Me*.

The Architects of Change navigation tab was designed to lead to a page on *Student Leadership*, which was created to convey why student leadership should be a focus and how it can be developed. Also nested under the Architects of Change header/tab was a page entitled *Change from Within.* This page illustrated the leadership development approach created by this author for the project (the approach develops leadership from the inside out). The *Change from Within* graphic (Figure 5) identifies intrapersonal skills, which equip students for the twenty-first century, and the chart shows a progressive framework or process to work towards the development of interpersonal skills necessary for student success in the twenty-first century workforce. This process of working from the *intrapersonal domain* to the *interpersonal domain*, or "from the inside out," guided the development of website activities. However, it should be noted that leadership development is a cyclic process that does not have a beginning or an end. In

order to graphically represent an avenue for leadership development, and for the practicality of teaching diverse learners, a linear process was shown. It is hoped this will lead to students finding their own cycles or paths of development.

The STEM content area on the website, which provided information on what STEM is and why it is important, also provided a brief explanation of the terms STEAM and SHTEAM, or S(H)TEAM. Meanwhile, some sample STEM activities were provided on the pages nested under this content area. Additionally, the Resources horizontal navigation tab provided an area for teachers (and students, if desired) to access resource links, etc., to support Grade 6 Science topics, and in particular, the Grade 6 topic of Extreme Environments. This unit was chosen as an example of how leadership activities might be incorporated using curricular material. It is anticipated that this section of the website will continue to develop and change over time.

The Activities/Assignments content area, containing a significant portion of the website material/resources, was divided into pages to sequentially develop the Level 1 and Level 2 leadership and career skills (via Leadership and STEM activities). Activities were accompanied by downloadable templates and/or assessment rubrics. To date, there appears to be a lack of readily available assessment templates and rubrics for some of the twenty-first century curricular competencies outlined by the BC Ministry of Education. It is hoped that these activities will further evolve and develop through the implementation and feedback process.

The Templates/Rubrics navigation tab/content area provided another way to access the previously mentioned templates and rubrics, by housing all the resources in one easily accessible area. This could be an easier way to quickly find a desired template or rubric (additional templates will be added to this area in future). Finally, a Bibliography horizontal navigation tab was included. As already noted, it is hoped that more resources and activities will continue to be

added to this project's living and evolving website. The question is, will student leadership skills be developed? Perhaps feedback submitted via the Contact Me/Feedback tab will assist in assessing and meeting this goal.

Major Project Implementation

After looking at the school calendar for the 2016-2017 school year, the October 21st Professional Development Day was initially chosen as an opportunity to present this master's project and solicit feedback from colleagues and other educators. However, due to time restraints, feedback was sought from practicing educators and university education students via alternate routes. Although questions addressing and assessing the development of student leadership and career skills would have been valuable to ask, these questions would have constituted "action research" and thus extended beyond the scope of this project. Therefore, for the purpose of this project, feedback addressed only the design and usability of the project's website. Questions addressed the following areas: Navigation, Visual Appeal, Clarity, Information, Leadership (skills and direction), Project Goal, STEM Resources, and Website Usefulness. This feedback provided a viable means of addressing the project's critical challenge question and goals.

Chapter 4 – Field/Beta Testing and Findings

Overall Criteria

The primary goal of this project was to answer the question: How can STEM education be a pathway to developing twenty-first century leadership and career skills? In order to answer this question, subordinate goals were used as the means of discerning the viability and overall success of the project's main goal. The subordinate goals were to provide easily shareable, downloadable, and usable activity ideas, assessment templates, lesson materials, and other resources (via an easily navigable platform), and to seek feedback on these resources. The deliverable part of this major project – the *Architects of Change: STEM Leadership* website – provided an ideal opportunity to solicit feedback and assess the outcomes of this project's goals.

Beta Testing – Methods and Process

The method used to test the intended outcome of this project was a Feedback/Contact Me page added to the *Architects of Change: STEM Leadership* website for users to voluntarily offer feedback and comments. The Feedback/Contact Me page was created by embedding a *Google Form* in the page, and the feedback form was designed to be simple for users to complete. The form contained ten questions, with an opportunity for both written and scaled responses (the scales were designed with a low to high numeric rating of 1 to 5). Users were given the opportunity to provide an email address if they wished, but anonymity was an option.

The field/beta testing of this project was initially going to be put forward to a small group of educators at a professional development day in the Coast Mountains School District (SD #82). However, due to time constraints and doubt about completing this project's website by the date required, an alternate route for acquiring feedback was sought. Feedback was thus solicited from students in the Faculty of Education at Vancouver Island University.

After reflecting on possible ways in which feedback could be obtained, some primary reasons for asking students in the Faculty of Education at Vancouver Island University for feedback were:

1. Education students are perhaps more likely to use online resources in the classroom and may be more current with regard to the aesthetic aspects of website design.
2. Education students are learning new methodologies and pedagogies for integrating technology and new curriculum into the classroom.
3. Feedback is generally more open and honest when it comes from individuals who have no connection to the author soliciting feedback. For example, there is the potential for feedback to be skewed on either side of the scale when colleagues who are also friends are asked for their opinions. It should be stated that although the field/beta testing has been informal, and not conducted as a formal survey, it is still important to receive information which is open, honest, and purposeful.

Feedback Questions. The questions on the Feedback/Contact Me page were categorized under the following headings: Navigation, Visual Appeal, Clarity, Information, Leadership Skills, Leadership Direction, Project Goal, STEM Resources, Website Usefulness, and Additional Comments. The design and usability of the project's website and resources were addressed by asking:

1. Are you able to easily navigate this website to find resources?
2. Are the website's tabs, icons, images and font clear, or are areas cluttered, confusing and hard to read?
3. Which area(s) of the website could be improved for clarity, if any?
4. Is there information you would like included on this website? If so, what?

5. From the *Change from Within* Leadership Development Chart (https://sites.google.com/site/leadersviastem/architects-of-change/student-leadership/changing-from-within), which leadership skills and competencies do you deem to be most important?
6. Does this website address these leadership skills and competencies in a purposeful way?
7. From the website activities/assignments page (https://sites.google.com/site/leadersviastem/Activities-Assignments), choose one activity/assignment and determine if it satisfies the goal of this project, which is to develop leadership skills and competencies via STEM education.
8. Are the website's STEM resources useful in working towards the leadership development goals?
9. Which resource, activity or assignment do you feel is most useful?
10. Additional comments.

Findings of Beta Testing

Due to feedback on this project being in real-time and ongoing, feedback from the first ten respondents formed the basis for the Findings of Beta Testing discussion for Chapter 4. The questions on the website's Feedback form used a 5-point scale, and although the website was visible to those with the website link, the *Architects of Change: STEM Leadership* website was not publicly searchable during the field/beta testing. This allowed for updates based on feedback, without the site being fully public. Furthermore, not fully publishing the website allowed for a limited group of educators to respond to the feedback request. Project feedback was generally very positive (as noted in Appendix S), and 50% of the respondents provided their email

addresses for further information or possible communication. Much was learned through the process of field/beta testing.

Navigation. Question 1 asked about website navigation and the ease with which website resources could be found. On a scale of 1 to 5, six respondents found the website “very easy” to navigate (5 out of 5), three respondents rated the website “easy" to navigate (4 out of 5), and one respondent was in the middle (3 out of 5). It should be noted that this Likert-type scale (i.e., using a rating of 1 to 5),

> Assumes that the strength/intensity of [the] experience is linear, i.e. on a continuum from strongly agree to strongly disagree, and makes the assumption that attitudes can be measured. Respondents may be offered a choice of five to seven or even nine pre-coded responses with the neutral point being neither agree nor disagree. (McLeod, 2008)

Meanwhile, written responses relating to website navigation revealed that seven respondents felt the horizontal tab navigation was clear, and three respondents felt they would have liked a more obvious hierarchy for the Architects of Change/Leadership, STEM, and Resources tabs. These respondents felt the tabs were not as prominent as they could or should have been, thus overlooking their relative importance.

Clarity and Visual Appeal. Regarding visual appeal (Question 2), seven respondents found the website’s contents clear to read and follow (with a rating of 4 out of 5), and three respondents chose a rating of 3 out of 5. Question 3 then asked for anecdotal feedback on areas of the website that could be improved for clarity. A great deal of useful feedback was provided, and the following points were offered. One respondent noticed that a few of the links on the Student Leadership page redirected the user from the page, rather than opening up another tab. Although most of the website links had been set to open up in different tabs, the Student

Leadership links were overlooked. Interestingly enough, another respondent commented that they did not like links opening up in new tabs, so maybe this is a matter of personal preference and an area that needs further study. Perhaps consistency should be the main consideration.

With respect to the *Architects of Change: STEM Leadership* website's visual appearance and overall look, three respondents commented that the website needed more visual appeal. One respondent felt that the dark background was "unappealing", while another respondent thought the look was too "monochromatic and dark". Another respondent commented that more images would have added appeal to the website. It was suggested that links should be embedded in images to add appeal and that additional "eye-catching" photos should be used. One respondent also commented that the website's space banner was "boring". Other minor notes were made about a couple of areas where the font style did not match, or where titles and terminology were inconsistent and caused some confusion.

Final feedback on Question 3 pertained to the *Change from Within* Leadership Development graphic. One respondent commented that the link to the interactive web viewer felt a bit "clumsy". This user also found the audio links difficult to access. Another respondent clicked on the image of the *Change from Within* graphic, rather than the link provided at the top for the interactive web viewer. Therefore, the user was unable to access the Gliffy interactive link. In moving forward, this feedback will be very useful for website updates.

Information. Question 4, which asked about additional information users would like, elicited seven responses, but two of these responses were questions (about plans for the future of the website or resources), and one was a comment stating the user liked the site. The remaining four responses provided some good suggestions for information to include on the website, including more STEM resources for students, activities on animals that survive in extreme

environments, examples of student work and testimonials, and information on why the website connected leadership and the study of extreme environments.

Leadership. Question 5 asked about which leadership skills and competencies respondents felt were most important. The answers from nine respondents stated a variety of skills including self-control and positive decision-making, adaptability, flexibility, ethical behaviour, self-evaluation, metacognition, empathy, responsibility, and communication. Two respondents stated Level 1 Domain Skills were important leadership skills, while four responses specifically commented on the importance of adaptability. The range of answers proved interesting, and the responses from feedback appear to support the importance of the Level 1 Intrapersonal Domain Skills for leadership development (as outlined on the *Change from Within* Leadership Development Chart).

Question 6 asked if the website addressed leadership skills and competencies in a purposeful way. Three individuals felt this was achieved very well (with a scaled response of 5 out of 5). Five individuals felt the goal was met well (with a rating of 4 out of 5 on the scale), while two individuals recorded a scaled response of 3 out of 5.

Project Goal. Question 7, which asked website users to chose one activity or assignment to determine if it met the project goal of developing leadership skills and competencies via STEM education, reported that five respondents felt the project goal was met very well (5 out of 5), while four respondents felt it was met well (4 out of 5), and one respondent recorded a scaled response of 3 out of 5.

STEM Resources. Regarding Question 8, the majority of individuals reported that the website's STEM resources were very useful in working towards the leadership development

goals (six individuals gave a 5 out of 5 rating). Three individuals rated the website's resources as useful (with a rating of 4 out of 5), and one individual posted a rating of 3 out of 5.

Website Usefulness. Question 9 addressed the website's usefulness by asking users which resources, activities or assignments they found to be the most useful. Responses were very positive about a variety of activities and resources on the website, and three respondents specifically noted they liked the range of activities provided. These respondents felt the range of activities allowed for flexibility, depending on the needs of the students and time constraints. One response also noted this allowed for self-directed learning, while still meeting the intended learning outcomes and overarching purpose of the Extreme Environments Unit study. Other responses commented more specifically on individual activities. For example, two respondents commented on the Expedition Log/Journal being a great activity idea to develop language skills and reflective abilities, while at the same time relating to the real world (one respondent also noted this was a great tool to develop intrapersonal leadership skills). One respondent noted he/she liked the two levels of inquiry, while another noted he/she liked the Level 1 Inquiry. Two respondents stated they "very much" liked the Level 2 Inquiry activities because the activities connected the theoretical study of extreme environments to the practical application of vehicle design (they noted the vehicle build was reflective of real world group work). It was also felt that the Level 2 Inquiry activities tied the elements of STEM Leadership together. Two respondents liked the information and/or collection of links found on the resources pages and under the STEM tab, while one respondent was very excited about the templates and rubrics. This respondent particularly liked the strategies for self-assessment and self-directed learning (and how this was tied to the rubrics). Therefore, the majority of feedback has supported the range and scope of activities and resources included on this project's website.

Summary

As presented in this chapter, the informal feedback received through field/beta testing has revealed that the majority of users appreciated the variety of ideas and information provided on the *Architects of Change: STEM Leadership* website. Meanwhile, a few comments have also indicated that more images and further organization of the horizontal tabs may facilitate navigation of the website's resources. This feedback, received via anecdotal and scaled responses, provides a foundation upon which conclusions and recommendations may be made in response to the critical question: How can STEM education be a pathway to developing twenty-first century leadership and career skills?

Has this project provided an example of one way in which STEM education can be a pathway to developing twenty-first century leadership and career skills? More specifically, has the Extreme Environments Unit, which offers activities using two levels of inquiry for both content and leadership development, achieved this goal? It is this author's view, based on feedback, that the primary and subordinate goals have been achieved. Feedback appears to support that leadership and career skills can potentially be developed through STEM education and the teaching of an Extreme Environments Unit, which in this case has used two levels of inquiry. Feedback appears to indicate that the *Architects of Change: STEM Leadership* website has provided easily shareable, downloadable, and usable resources (via an easily navigable platform), and has thus provided a means to achieve this project's primary goal (to develop twenty-first century leadership and career skills via STEM education).

Chapter 5 – Conclusions and Recommendations

Overall Criteria

Through an integrated approach to learning, the *Architects of Change: STEM Leadership* website has provided teachers (and students) with resources that may be helpful in encouraging students to take control of their learning, and to thereby become leaders – leaders who are able to create change… for themselves, for others, and for society. The importance of twenty-first century skills such as curiosity, creativity, initiative, multi-disciplinary thinking, empathy, among others, are critical for the collaboration, communication, and interaction needed in today's world. As the BC Ministry of Education (2015) noted, leadership is one of the twenty-first century competencies that is needed and should be developed (p. 6). The workforce needs individuals who have the leadership and career skills and competencies to manage an increasingly unpredictable, technological and rapidly changing world.

The Chapter 2 Literature Review of this master's project makes a case for STEM education being a natural pathway to develop many of the required skills students need to succeed in today's world, given the rapid pace of technological change (Buckner & Boyd, 2015; Council of Canadian Academies, 2015; DeCoito, 2014; Johnson, Adams Becker, Estrada, & Freeman, 2015). The deliberate integration of STEM education (which can foster an ability to address real-world problems through the use of problem-based learning, project-based learning, inquiry, and social learning) aligns well with today's need for a workforce to have twenty-first century leadership and career skills. STEM activities can foster deep and powerful learning, an important precursor for developing a growth mindset (Dweck, 2015), while the student-centric and student-directed inquiry process is a natural pathway to developing leadership and career skills such as creativity, collaboration, communication, and responsibility (to name just a few).

The literature review, which provided the foundational theory for the development of the *Architects of Change: STEM Leadership* website, led to the idea and suggestion by this author that leadership development might be more successfully achieved by implementing activities to develop leadership skills and competencies in a manner that focuses on development "from the inside out." Therefore, the *Change from Within* Leadership Development approach was created and implemented throughout the activities and assignments to support this project's goal.

As illustrated on the *Change from Within* Leadership Development graphic (Figure 5), it is proposed that the development of leadership and career skills can be divided into two domains – the Level 1 Intrapersonal Domain, and the Level 2 Interpersonal Domain. It is suggested that leadership development is a naturally evolving process that is cyclic in nature (although the illustration and suggested implementation plan for the intrapersonal and interpersonal skills are represented as linear in nature, for logistical and implementation purposes). The Level 1 Intrapersonal Skills identified on the *Change from Within* Leadership Development graphic include: Flexibility & Adaptability, Initiative & Self-Direction, Productivity & Work Ethic, and Self-Evaluation & Metacognition. The Level 2 Interpersonal Skills identified on the graphic include: Global & Cultural Understanding, Collaboration, Communication, Responsibility, and Ethical Behaviour. In addition, at the core of the leadership development graphic, Empathy and Cognition are illustrated as being pivotal in fostering skills such as Problem-Solving, Critical Thinking, Creativity, and Innovation. This graphic has been the central focus around which website activities and assignments have been developed. Therefore, the success of this project in answering the critical question may be dependent on understanding and accepting the *Change from Within* Leadership Development graphic (at least in general terms of what constitutes leadership).

Conclusions

Results from this project's field/beta testing seem to indicate that STEM education can be a suitable pathway for developing leadership and career skills. In particular, the *Architects of Change: STEM Leadership* website, developed as the deliverable part of this major project (offering lessons, resources and activities relating to the study of Extreme Environments), provided an example of a way in which leadership and career skills may be developed via STEM education. The website presented educators with a Site Map (and drop down navigation tab menus) leading to information on Leadership, STEM Resources, Extreme Environments Resources, Activities and Assignments (integrating the aforementioned information), and Templates to accompany the activities and assignments. Bibliography and Feedback/Contact Me pages were also included on the website. The Feedback/Contact Me page proved to be very useful for the submission of feedback during the field/beta testing stage.

One question that arose during the field/beta testing of the *Architects of Change: STEM Leadership* website asked why the study of Extreme Environments had been chosen as a pathway for developing leadership skills. As one who spent many years investigating and inquiring, the integration of Science, Technology, Engineering, and Math appeared to be a natural intertwining of subjects, and well-suited to the study of Extreme Environments. At the heart of exploration is the need to collaborate, communicate, and demonstrate leadership in the discovery and uncovering of the unknown. The exploration of Extreme Environments is ideal for co-constructing ideas and vehicles for exploration (figuratively and literally). This naturally integrates the STEM subjects in a real-world manner. Through collaboration and communication, solutions may be achieved, and the advancement of knowledge may occur. The activities on the *Architects of Change: STEM Leadership* website provided examples of how the

STEM subjects can be integrated. Activities also worked towards developing the identified leadership and career skills and competencies. It should be noted that although information may sometimes be provided under separate categories or tabs, it is the research and investigation (and subsequent manipulation of information and integration of ideas) that is critical to the inquiry and discovery process. Activities were designed to promote this inquiry process, which ultimately allowed for the application of skills and competencies – with respect to both content and leadership.

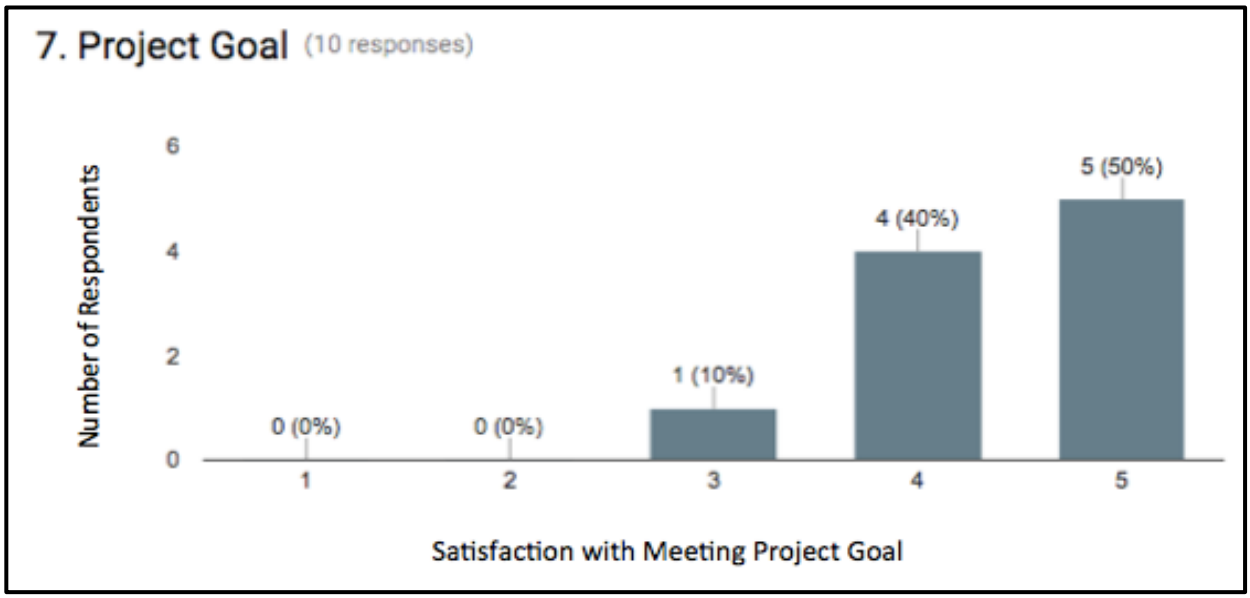

Figure 6. Feedback responses from Question #7 indicated that 50% of the respondents felt the project's goals were met very well (5 out of 5), while 40% of the respondents felt the goals were met well (4 out of 5), and one respondent submitted a 3 out of 5 rating.

Evaluation of feedback from the field/beta testing found that the majority of respondents felt the *Architects of Change: STEM Leadership* website met the project's goal, which was to answer: How can STEM education be a suitable pathway for developing leadership and career skills? Ninety percent of the scaled responses stated the project's primary goal was met "well" or "very well" (Figure 6), and written responses indicated that users were happy with the varied

resources and activities. Ninety percent of users rated the STEM resources as “useful” or “very useful.” Although 80% of scaled responses indicated the project’s leadership development goals were met, it was interesting to note that questions posed by users indicated that users had not previously considered leadership in the manner presented on the website (this was determined from a few additional questions under the “Additional Comments” section). Meanwhile, the main area(s) that elicited comments and feedback, with suggestions for improvement, related to the clarity and visual aspects of the website. Scaled feedback (Appendix S) supported the written comments. No respondents rated the visual appeal as “very clear,” while 70% of users felt the visual appeal was “clear” (indicated by a 4 out of 5 rating). Results appear to support the way in which feedback was obtained (i.e., from Education students at Vancouver Island University, who have more than likely been exposed to current trends in technology and education).

Recommendations

Based on feedback from field study results, updates have been suggested and changes have been recommended for the *Architects of Change: STEM Leadership* website, which primarily relate to the overall look of the website. For example, a change has been proposed to lighten the appearance of the website’s background/theme, and it has been suggested that more graphics should be added to the website to enhance the visual representation. Furthermore, the Extreme Environments links (on pages under the Resources tab) could easily be embedded in images, which would improve the visual appeal. Another area that should be improved or updated, based on feedback and recommendations (and an area that had been considered prior to field/beta testing), is the *Change from Within* Leadership Development graphic. It was suggested that this graphic should be embedded in the *Google Sites* page. Further feedback will confirm whether this is a problematic area that should be addressed.

Regarding navigation, this author has proposed that the hierarchy of tabs on the horizontal navigation bar should be re-evaluated to determine if there is a better way to indicate the importance of tabs/pages and resources. During the development of the website, it was felt that working in order from left to right would indicate the relative importance of pages/tabs. However, although this may seem logical to an older generation of educators, this may not be obvious and logical to a younger generation of educators (i.e., millennials), who may rank tab size and/or colour as more important hierarchical features. A post by Crestodina (2013) stated, "Psychology studies show that attention and retention are highest for things that appear at the beginning and at the end. It's called the 'serial position effect,' and it's based on the principles of primacy and recency" (n.p.). This indicates that the most important content areas should be put at the beginning of the tab navigation, while the least important areas should go in the middle. It is suggested that contact information should go at the end. Crestodina (2013) also provided an example of strong contrast (i.e., dark and light colour) as being a good way to differentiate between primary and secondary navigation in the horizontal navigation bar or header. Therefore, tab hierarchy may be something to evaluate for updates and future website development.

A few minor changes with respect to how links open (i.e., on the *Leadership* page), adjustment to terminology in a few areas, and checking for font consistency, are further recommendations that will produce a polished look to the website. After all, it is hoped that this website will be a resource that educators choose to use to promote leadership development via STEM.

The completion of this project has provided an opportunity to reflect on how the implementation stage could have been conducted differently, using different approaches,

methodologies, or timeframes, to render different or more definitive end results. For example, this author suggests that feedback from a larger sample size could have led to different results, especially if feedback came from a more diverse group of educators. A larger and more diverse sample size for feedback could provide a better overall picture of educators' views; however, this could also provide feedback that is less specific and less useful. Meanwhile, soliciting feedback over a longer period of time, or using a different tool or manner (as opposed to using a Google Form) could have rendered different results. Adjustments to the website's contents, presentation, and navigation of resources, would also lead to different feedback results, as indicated by feedback comments.

Suggestions for future study include the continued research and development of a range of tools (i.e., rubrics, templates, etc.) for the formative assessment of twenty-first century skills and competencies, especially those relating to leadership and career skills. However, it is this author's view that in order for these tools and methods of assessment to be deemed useful, they would need to be 1) compatible with and support the development of the chosen skills and competencies, and 2) universally recognized and accepted as "measures" of development (from school through to employment). Action research would, therefore, add additional insight and depth of knowledge and understanding to this area.

Finally, feedback and input gathered via the feedback form on the *Architects of Change: STEM Leadership* website is an example of the ideation process so prominent in the technology and engineering sectors, and indeed in STEM education today. The diverse opinions and input, which serve as the impetus for change and the reworking of ideas, can lead to positive outcomes and results – in this case, it is hoped the result is a user-friendly website with effective lessons and useful resources, which meet the goal of developing leadership and career skills via STEM

education. Therefore, it is recommended that the website's feedback form remains open for further input and suggestions, so future change and learning may occur. In time, perhaps more resources will be developed and shared to the *Architects of Change: STEM Leadership* website, and perhaps the conversation will extend beyond the borders of BC to include a more global view and perspective. As the literature indicates, a growth mindset, which focuses on the process of learning, and a constructionist approach where learning occurs through constructing real-world inventions, not only benefits our students but benefits us all. With an open mind and a willingness to accept and seek input, perhaps we can help students grow to be leaders and activators of change. Teachers have the potential to be change agents when student-centric pedagogy drives instruction. Leadership is a collaborative process, upon which our future depends.

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Table 1
Definition of Terms (with references)

Definitions are provided to assist in understanding the scope and purpose of this project.

Term/Word	Definition	Source
Competency (Twenty-First Century)	The product of deeper learning is transferable knowledge, including content knowledge in a domain and knowledge of how, why, and when to apply this knowledge to answer questions and solve problems. We refer to this blend of both knowledge and skills as "21st century competencies."	Pellegrino & Hilton, 2013, p. 6. http://dx.doi.org/10.17226/13398
Constructionism	Constructionism is built on the theory that learning happens best when learners tinker, explore, and construct understanding through building real-world inventions to share with others. "Constructionism...shares constructivism's connotation of learning as 'building knowledge structures'...It then adds the idea that this happens... in a context where the learner is consciously engaged in constructing a public entity".	Donaldson (2014) http://www.digitalpedagogylab.com/hybridped/constructionism-reborn/ Papert & Harel, 1991, p. 1. http://namodemello.com.br/pdf/tendencias/situatingconstrutivism.pdf
Deeper Learning	"An umbrella term for the skills and knowledge students must possess to succeed in 21st century jobs and civic life." Today's workforce requires individuals to be able to master academic content, collaborate and communicate effectively, think critically, and become life-long learners. The deeper learning framework, therefore, "includes six competencies that are essential to prepare students to achieve at high levels: 1) Master core academic content 2) Think critically and solve complex problems 3) Work collaboratively 4) Communicate effectively 5. Learn how to learn 6. Develop academic mindsets."	Hewlett Foundation, 2013, p. 1. http://www.hewlett.org/uploads/documents/Deeper_Learning_Defined__April_2013.pdf
Digital Divide	An economic and social inequality regarding the access to and use of Information and Communication Technologies (ICT), not only in terms of devices, but also in terms of existing bandwidth. A digital divide encompasses both the disparity in ownership or accessibility to technology, and the skills to use the technology.	Wikipedia, 2015, para. 3. https://en.wikipedia.org/wiki/Digital_divide

Experiential learning	The process of learning through experience and reflecting on what one is doing. The reflection aspect differentiates experiential learning from hands-on learning (a form of experiential learning). "According to the four-stage learning cycle, immediate or concrete experiences are the basis for observations and reflections. These reflections are assimilated and distilled into abstract concepts from which new implications for action can be drawn. These implications can be actively tested and serve as guides in creating new experiences."	Kolb, D. A., Boyatzis, R. E., & Mainemelis, C. (2001, p. 3) http://www.d.umn.edu/~kgilbert/educ5165-731/Readings/experiential-learning-theory.pdf
Inquiry-based learning	An approach to teaching and learning that starts by posing problems or scenarios, and places students' questions, observations, and ideas at the centre of the learning experience. Students become actively engaged in their learning, pursuing open-ended questions in an authentic manner.	Edelson, D. C., Gordin, D. N., & Pea, R. D. (1999). https://hal.archives-ouvertes.fr/file/index/docid/190609/filename/A101_Edelson_etal_99.pdf
Personalized learning	The personalization of learning aimed to meet the wide variety of learning needs, interests, or cultural backgrounds of individual students. Personalized learning is a learner-centred approach where students have a voice and choice on what and how they learn. Learners participate in the design of their learning experiences, based on their interests, aspirations, and passions. Educational programs, resources, and support strategies are selected by the learner to meet their learning objectives.	(Bray & McClaskey, 2012) http://education.ky.gov/school/innov/Documents/BB-KM-Personalizedlearningchart-2012.pdf
Problem-based learning	A student-centred pedagogy where students solve an open-ended problem to learn about a subject. "PBL actively engages the student in building their own understanding of complex issues, which places it in the tradition of constructivism. The use of PBL techniques means that how a problem is approached will likely result in a variety of viable solutions; its premise is that some complex problems will in fact have more than one solution."	(HLWIKI International, 2015, n.p.) http://hlwiki.slais.ubc.ca/index.php/Problem-based_learning

Project-based learning	A teaching/learning method in which students actively explore (for an extended period of time) real-world, complex problems and challenges to gain knowledge, skills, and a deeper understanding of these issues.	Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). http://www.tandfonline.com/doi/abs/10.1080/00461520.1991.9653139
Situated cognition	A theory that posits that knowing and doing are inseparable. It is argued that knowledge is situated, "being in part a product of the activity, context, and culture in which it is developed and used", thus it is bound to social-cultural and physical contexts. It is felt that conventional schooling often ignores the importance of school culture on learning.	Brown, J. S., Collins, A., & Duguid, P. (1989). http://www.johnseelybrown.com/Situated%20Cognition%20and%20the%20culture%20of%20learning.pdf
Skill (Twenty-First Century)	A skill outlines *what* types of ability an individual needs to perform a specific activity or job (as opposed to *why*).	Pellegrino & Hilton, 2013, p. 6 http://dx.doi.org/10.17226/13398
STEM/ STEAM	STEM, coined by the National Science Foundation (DeCoito, 2014), is the intermixing of: Science, Technology, Engineering, and Mathematics. However, STEM is not just a grouping of subject areas, but it is their "intersection" and a holistic approach to solving problems (DeCoito, 2014; Jolly, 2014). STEAM (or SHTEAM) includes the Arts and Humanities as important components and integral to a holistic approach.	DeCoito, I. (2014). http://es.krcmar.ca/sites/default/files/2014_Winter_Focusing%20on%20STEM_0.pdf Jolly, A. (2014, June 17). http://www.edweek.org/tm/articles/2014/06/17/ctq_jolly_stem.html

Appendix A

Level 1 Skills Self-Assessment

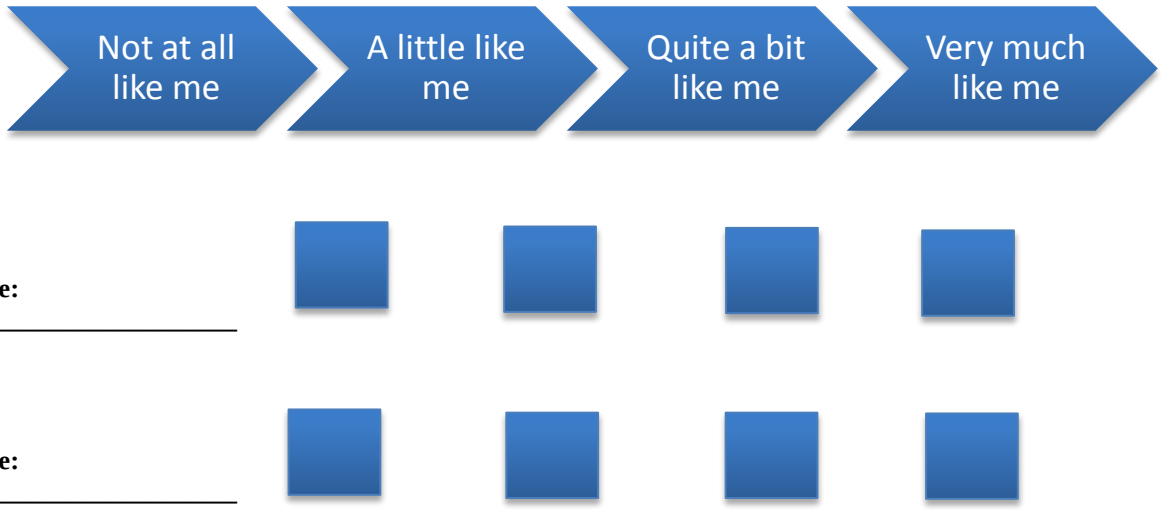
Skill	Your Skill Level	Strategies for Improvement
Persistence	Strength Needs Improvement	
Resilience	Strength Needs Improvement	
Self-control and positive decision-making	Strength Needs Improvement	
Self-evaluation	Strength Needs Improvement	
Listening	Strength Needs Improvement	
Punctuality	Strength Needs Improvement	
Responsibility	Strength Needs Improvement	
Initiative	Strength Needs Improvement	
Compassion	Strength Needs Improvement	
Adaptability	Strength Needs Improvement	
Worth ethic	Strength Needs Improvement	
Dependability	Strength Needs Improvement	

Appendix B

Level 1 Intrapersonal Domain Skills: Flexibility and Adaptability Template

Name:

Flexibility & Adaptability



You will need to include evidence that you have worked on these skills in your portfolio.

Being flexible and adaptable means:	**If this is very much like me then:**
• Being okay with different responsibilities, schedules, and circumstances • Adjusting to change and being flexible • Using feedback and suggestions • Being positive about **all** feedback • Balancing different opinions to find solutions	• I can show I do different tasks in a variety of ways • I am okay with change • I can 'go with the flow' • I use feedback from others • I am okay with constructive criticism • I use different viewpoints to find solutions • I am confident about doing these things

Appendix C

Level 1 Intrapersonal Domain Skills: Initiative and Self-Direction Template

Name:

Initiative and Self-Direction

Date: _____

Date: _____

You will need to include evidence that you have worked on these skills in your portfolio.

Showing initiative and self-direction means:	**If this is very much like me then:**
• Setting short-term and long-term goals • Using time wisely • Defining, setting an order, and completing tasks • Exploring ideas and choosing to learn • Committing to the process of learning • Reflecting on past experiences to improve for the future • Taking the next step!	• I can show I know how to set meaningful goals (short-term and long-term) • I can schedule my time • I can show I know how to organize and complete tasks • I can research topics of interest without being prompted • I can ask questions and inquire • I keep my mind open to ideas to improve how I do things • I am confident about doing these things

Appendix D

Level 1 Intrapersonal Domain Skills: Productivity and Work Ethic Template

Name:

Productivity and Work Ethic

Date: _____

Date: _____

You will need to include evidence that you have worked on these skills in your portfolio.

Being productive and showing work ethic means:	**If this is very much like me then:**
• Setting and meeting goals • Staying on top of tasks by planning and organizing • Collaborating and cooperating • Being positive about tasks • Participating actively • Being reliable and punctual • Being respectful • Being accountable for results	• I can show I can meet the goals I have set • I stay organized and complete tasks • I can work with others to meet my goals • I am positive when I work • I get involved; I don't let others do all the work • I can show I am reliable and on time • I use positive language and actions • I take responsibility for my work • I am confident about doing these things

Appendix E

Level 1 Intrapersonal Domain Skills: Self-Evaluation and Metacognition Template

Name:

Self-Evaluation and Metacognition

Date: _____

Date: _____

You will need to include evidence that you have worked on these skills in your portfolio.

Self-evaluation and metacognition means:	**If this is very much like me then:**
• 'Thinking about thinking' • Learning about thinking processes • Using thinking strategies such as brainstorming, mind-mapping, visual or design thinking, creative thinking, sequencing, etc. • Continually reflecting about what you do • Thinking about the outcomes of your thinking strategies • Thinking about how you can improve	• I can show that I think about what I do through my reflective journal entries and by using other thinking strategies • I can explain my thinking processes to others • I can show I think about the outcomes of my thinking strategies through my reflections • I think about how I can improve and I make a change • I am confident about doing these things

Appendix F

Level 1 Activity – Advertisement for an Extreme Environment Marking Rubric

Criteria (Mark out of 20 x 2 = 40)

Category	4	3	2	1
Organization	Presents information in a logical, interesting sequence which can be easily followed.	Presents information in a fairly logical sequence which can be followed with little confusion.	It is difficult to follow the presentation because it jumps around.	Presentation can not be followed because there is no sequence of information.
Content Knowledge	Demonstrates full knowledge with explanations and elaboration on the topics required.	Demonstrates full knowledge on all but one topic.	Demonstrates full knowledge on all but two topics.	Demonstrates little knowledge on several topics.
Visuals	Visuals are used creatively to reinforce text and presentation.	Visuals relate to text and presentation.	Visuals are occasionally used, but rarely support text and presentation.	Visual is unrelated to the topic.
Presentation: mechanics, overall grammar, spelling, language/terms usage, audience consideration, neat	Presentation is of exceptional quality with respect to mechanics and overall impression.	Presentation meets expectations with respect to mechanics and overall impression.	Presentation minimally meets expectations with respect to mechanics and overall impression.	Presentation does not meet expectations with respect to mechanics and overall impression.
Sources (at least 3)	Cites 3 or more sources of information appropriately. Cites images.	Cites 3 or more sources of information. Cites images. A few formatting errors.	Cites fewer than 3 sources of information, or images not cited. Formatting errors.	Cites 1 source of information. More effort needed.

Intrapersonal Skills (student comment/evidence - worth 5 marks):

_____
_____
_____
_____
_____

Teacher comment:

_____
_____

Total Mark: /45

Appendix G

Level 2 Skills Self-Assessment

Skill	Your Skill Level	Strategies for Improvement
Appreciating diversity	Strength Needs Improvement	
Global and cultural understanding	Strength Needs Improvement	
Communicating clearly (verbally)	Strength Needs Improvement	
Listening	Strength Needs Improvement	
Non-verbal communication	Strength Needs Improvement	
Responsibility	Strength Needs Improvement	
Collaboration	Strength Needs Improvement	
Ethical behaviour	Strength Needs Improvement	
Digital citizenship	Strength Needs Improvement	
Getting along with others	Strength Needs Improvement	
Social awareness	Strength Needs Improvement	
Empathy	Strength Needs Improvement	

Appendix H

Level 2 Interpersonal Domain Skills: Collaboration Template

Name:

Collaboration

Date: _____

Date: _____

You will need to include evidence that you have worked on these skills in your portfolio.

Collaborating means:	**If this is very much like me then:**
• Being a team player • Listening attentively • Asking thoughtful questions to gain a better understanding • Showing respect and sincere appreciation • Being willing to take the first step to help out • Seeking to find answers and make connections • Creating an environment of trust to help build relationships	• I can get along with others (I don't use 'put-downs') • I show interest and curiosity in what others say and do • I thank others for their help, and I provide non-judgmental feedback and talk positively about others • I offer support to others without being prompted • I keep my mind open to ideas and suggestions by others • I am confident about doing these things

Appendix I

Level 2 Interpersonal Domain Skills: Communication Template

Name:

Communication

Date: _____

Date: _____

You will need to include evidence that you have worked on these skills in your portfolio.

Being a good communicator means:	**If this is very much like me then:**
• Tailoring how you communicate to relate to your audience • Knowing when to speak and when to listen • Being attentive and listening carefully • Recognizing and paying attention to non-verbal cues • Asking questions to gain a better understanding • Making your message clear, concise, specific, and easily understood * Eliminating distracting behaviours	• I adjust what I say, depending on whom I talk to • I show interest and curiosity in what others say, by being quiet when they talk, looking at the speaker, focusing on the message, and asking questions to gain understanding • I understand the gestures, body language, and facial expressions of others, and I monitor my own • I think carefully about what I say or write • I am confident about doing these things

Appendix J

Level 2 Interpersonal Domain Skills: Ethical Behaviour Template

Name:

Ethical Behaviour

Date: _____

Date: _____

You will need to include evidence that you have worked on these skills in your portfolio.

Ethical behaviour means:	**If this is very much like me then:**
• Demonstrating values that are typically accepted as 'good' • Trying to be fair and non-judgmental in all situations • Exhibiting honesty and dignity • Believing in equality • Respecting diversity and individual rights • Having a sense of pride in oneself; self-respect	• I think about my actions and believe in the choices I make • I listen to others without bias and make decisions using the facts • I always try to tell the truth to the best of my ability • I can accept people for who they are • I acknowledge and respect unique and different ideas, opinions, peoples and cultures • I am confident about doing these things

Appendix K

Level 2 Interpersonal Domain Skills: Global and Cultural Understanding Template

Name:

Global and Cultural Understanding

Date: _____

Date: _____

You will need to include evidence that you have worked on these skills in your portfolio.

Global and cultural understanding means:	**If this is very much like me then:**
• Understanding and respecting people from different cultures • Interacting effectively with diverse groups or cultures • Respecting diversity • Stepping back from ourselves and becoming aware of our cultural values, beliefs and perceptions • Managing personal attitudes and beliefs toward other cultures, customs, and traditions	• I show I am interested in learning about and interacting with different cultures (I don't exhibit prejudice) • I don't impose my own views and beliefs on others • I am accepting of new ways of doing things, and I try to learn about different customs and traditions • I respect individual differences and cultural or social norms • I am confident about doing these things

Appendix L

Level 2 Interpersonal Domain Skills: Responsibility Template

Name:

Responsibility

Date: _____

Date: _____

You will need to include evidence that you have worked on these skills in your portfolio.

Taking responsibility means:	**If this is very much like me then:**
• Owning choices you have made • Being reliable and dependable • Following through on obligations without direct supervision • Accepting ownership for actions you have taken and for any results or outcomes • Accepting one's obligation to act for the benefit of society • Getting involved in community endeavours and thinking beyond yourself	• I accept the consequences of my choices or actions, even when I do not like the result • I meet my commitments and I get to places on time • I do what I say I am going to do • I do things for the benefit of my school, community, and society (i.e., I volunteer my time) • I contribute to our world being a better place • I am confident about doing these things

Appendix M

Expedition Log (Journal) Rubric

Criteria (Mark out of 24)

Category	4	3	2	1
Log entries are structured and relevant to a unit/topic focus (x2)	All or almost all of the entries have structure and focus.	Most entries have structure and focus.	Few entries have structure and focus.	Work has been submitted, but there is no structure and focus.
Reflections (x2)	Feelings and thoughts are revealed in all or almost all of the entries and show a deep level of thinking / self-reflection.	Feelings and thoughts are revealed in many entries and most show a deep level of thinking / self-reflection.	Feelings and thoughts are revealed in few of the entries, but do not show a deep level of thinking /self-reflection.	No feelings or thoughts are revealed in the entries. There is no evidence of reflection.
Format (when applicable)	The proper format has been followed, when applicable.	The proper format has been followed for most of the entries, when applicable.	The proper format has been followed for few of the entries, when applicable.	The proper format has not been followed for any of the entries.
Completion	All entries are present, in order, and together.	All entries are present, but are either not together or in order.	Not all entries are present, but they are together or in order.	Not all entries are present, nor are they together or in order.

Leadership Skills (student comment/evidence of development or awareness - worth 10 marks):

_____
_____
_____
_____
_____

Teacher comment:

_____
_____

Total Mark: /34

Appendix N

Level 2 Activity – Vehicle Build Marking Rubric

Criteria (Mark out of 35 x 2 = 70)

Category	4	3	2	1
Completion of Vehicle Design Chart Pages 1 and 2 (Individual activity) **X 2**	All sections completed thoughtfully with sufficient detail.	All but one section completed thoughtfully with sufficient detail.	More than one section not completed and/or insufficient detail provided.	Much more effort is needed towards completion of the chart.
Ideation Sketches, reflections or written responses, and vehicle design shows progression of ideas. **X 2**	Fully shows logical progression of ideas or reworking of ideas, and incorporates feedback to modify design.	Mostly shows logical progression of ideas or reworking of ideas, and incorporates feedback to modify design.	Shows some progression and reworking of ideas, and attempts to incorporate feedback to modify design.	Progression of ideas and use of feedback is not quite there yet.
Collaboration and other Interpersonal skills (Responsibility Communication, Ethical Behaviour, Global & Cultural)	Able to collaborate well with peers. Interactions are positive and contribute to the group's goals.	Able to collaborate with peers. Interactions are mostly positive and contribute to the group's goals.	Somewhat able to collaborate with peers. Interactions can contribute to the group's goals.	Interpersonal skills are still developing.
Vehicle Features and Use	Appropriate for exploring this environment. Vehicle's features and how they are connected to purpose and environment have been clearly explained (or illustrated/shown) in detail.	Appropriate for exploring this environment. Vehicle's features and how they are connected to purpose and environment have been explained (or illustrated/shown).	Somewhat appropriate for exploring this environment. **OR** Vehicle's features are somewhat connected to purpose and environment. **OR** Little explanation.	Not appropriate for exploring this environment. Simple or unconnected explanations of purpose /environment.
Model **X2**	A creative, innovative, and detailed model has been created.	A detailed model has been created.	A somewhat detailed model has been created.	An incomplete or very simple model has been created.

Teacher comment:

_____

_____

_____

Total Mark: /70

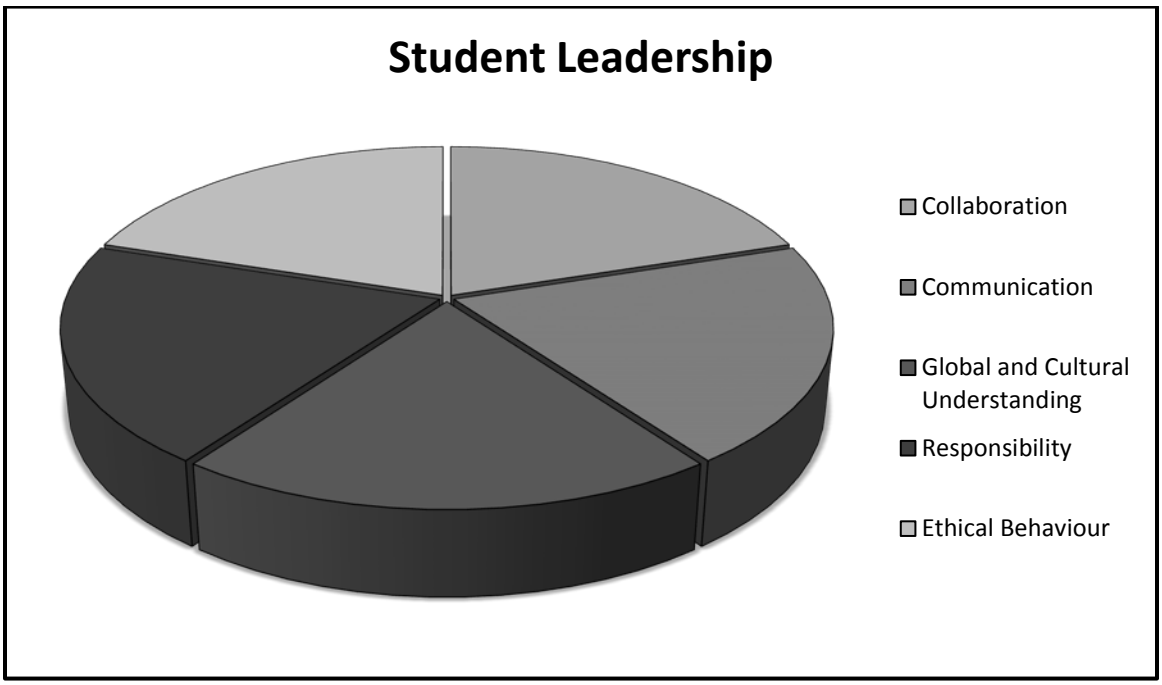
Appendix O

Leadership in Action – Leadership Development and Change Template

Name:

Leadership Development and Change

How have YOU made a change?



Which leadership skill(s) have you improved?

_____

_____

Write an Expedition Log / Journal entry to reflect on how you have improved your leadership skill(s). Be specific and provide examples of actions (work, activities, etc.) that support this. Focus honestly on how you affect others and the world around you (past and present).

Appendix P

Leadership in Action – Poster Presentation Marking Rubric

Criteria (Mark out of 40)

Category	4	3	2	1
Mission Statement Card	Mission statement fully addresses the cause, action, and impact.	Mission statement almost fully addresses the cause, action, and impact.	One or more areas not addressed in sufficient detail.	Not quite there yet.
Paragraphs on the Extreme Environment	Provides sufficient detail on relevant areas of the extreme environment. Well formatted.	Provides sufficient detail on relevant areas of the extreme environment. Well formatted with one or two minor errors.	Provides insufficient detail on relevant areas of the extreme environment.	Not quite there yet.
Justification for the Exploration Vehicle Build	Able to fully justify the need for the exploration vehicle.	Able to justify the need for the exploration vehicle, but missing a few logical connections.	Missing important justifications for exploration vehicle build.	Not quite there yet.
Vehicle's Features and Use	Appropriate for exploring this environment. Vehicle's features and how they are connected to purpose and environment have been clearly explained (or illustrated/shown) in detail.	Appropriate for exploring this environment. Vehicle's features and how they are connected to purpose and environment have been explained (or illustrated/shown).	Somewhat appropriate for exploring this environment. **OR** Vehicle's features are somewhat connected to purpose and environment. **OR** Little explanation.	Not appropriate for exploring this environment. Simple or unconnected explanations of purpose /environment.
Group's Task Card	A creative, innovative, and detailed model has been created.	A detailed model has been created.	A somewhat detailed model has been created.	An incomplete or very simple model has been created.
Materials List	Tasks have been clearly recorded and defined.	Most tasks have been clearly recorded and defined.	One or two tasks not identified or defined.	Many tasks not identified or defined.
Steps Outlining the Vehicle Build Process (procedure).	All significant steps have been outlined in the procedure.	All but one significant step have been outlined in the procedure.	A few significant steps have not been outlined in the procedure.	Many steps are missing from the procedure.
Group Sketch	Sketch clearly illustrates position and function of parts. Sketch has been enlarged using the grid method.	Sketch somewhat illustrates position and function of some parts. Sketch has been enlarged using the grid method.	Sketch illustrates position and function of parts. Sketch has not been enlarged using the grid method.	Sketch not completed as outlined and not clear.
Summary Card (Reflection of the Process)	Reflection on lessons learned through the design process is clearly evident in the summary.	Reflection on lessons learned through the design process is somewhat evident in the summary.	A summary is included, but there is no evidence of reflection of the design process.	Not quite there yet.
Bibliography and/or Acknowledgements	All sources cited appropriately.	All sources but one cited appropriately, or one or two minor errors in formatting.	Many errors in citing sources appropriately.	Not quite there yet.

Teacher comment:

_____

_____

_____

Appendix Q

Leadership in Action – Larger Audience Presentation: Student Self Assessment

Mark out of 32 (2 X 16)

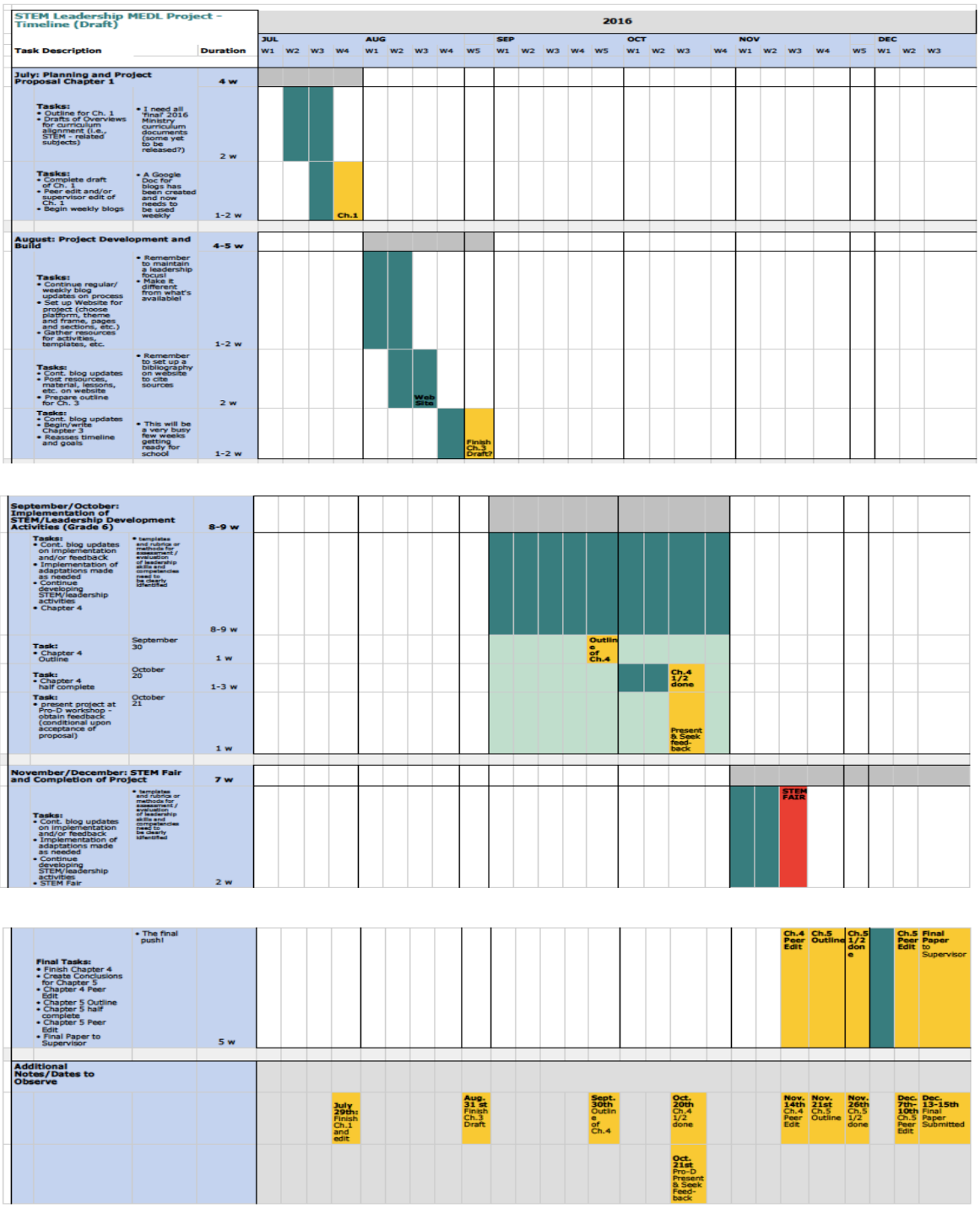
Category	4	3	2	1
Contribution to Group Goals	I willingly work towards group goals and accept my individual responsibilities within the group.	With occasional prompting, I willingly work towards group goals and accept my individual responsibilities within the group.	With fairly regular prompting, I work towards group goals and accept my individual responsibilities within the group.	I only work towards group goals when prompted.
Consideration of Others	I am sensitive to the feelings and learning needs of others, and I value the opinion and skills of all group members.	I am sensitive to the feelings of others, and I encourage their participation.	I am sensitive to the feelings of others.	I need occasional reminders to be sensitive to the feelings of others.
Contribution Of Knowledge	I actively and regularly contribute knowledge, opinions, and skills to group activities without the need for prompts or reminders.	I contribute knowledge, opinions, and skills to group activities without the need for prompts or reminders.	I contribute to group activities with occasional prompts or reminders.	I contribute to group activities only when prompted.
Working and Sharing with Others	I help the group make necessary changes when needed, and I do assigned work without reminders.	I willingly participate to make necessary changes, and I usually do assigned work without reminders.	I participate to make necessary changes when prompted, and I need reminders to do the assigned work.	I need encouragement to make necessary changes, and I rely on others to do the work.
Overall Score	Comments:			

Total Mark: /32

Appendix R

MEdL Project Timeline

Timeline: Fenella's MEDL STEM-Leadership Project - Project Timeline

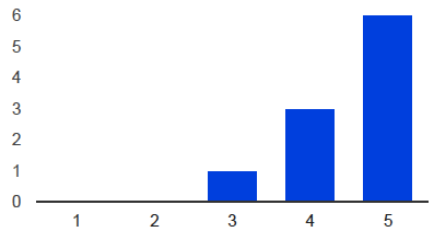


Appendix S

Chapter 4 – Feedback Data from
Architects of Change: STEM Leadership Website

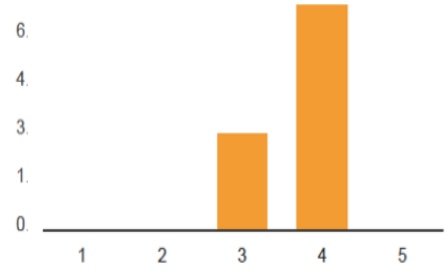
Note: Some feedback questions rendered data that could be graphically represented, and some questions asked for written responses. The graphs below are from four questions (1, 2, 6, 8).

1. Navigation



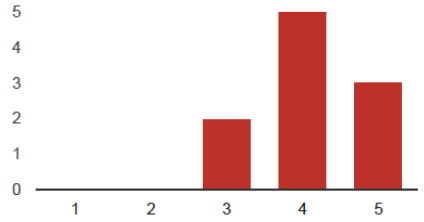
No, not at all: 1	**0**	0%
2	**0**	0%
3	**1**	10%
4	**3**	30%
Yes, very easily: 5	**6**	60%

2. Visual Appeal



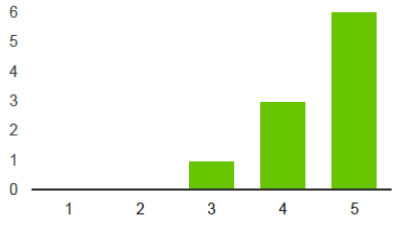
Not clear at all: 1	**0**	0%
2	**0**	0%
3	**3**	30%
4	**7**	70%
Very clear: 5	**0**	0%

6. Leadership Direction



Not at all: 1	**0**	0%
2	**0**	0%
3	**2**	20%
4	**5**	50%
Yes, very well: 5	**3**	30%

8. STEM Resources



Not at all: 1	**0**	0%
2	**0**	0%
3	**1**	10%
4	**3**	30%
Yes, very useful.: 5	**6**	60%