Seeing the forest for the trees: Elementary STEM environments that nurture creativity and innovation

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University of Northern Iowa

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SEEING THE FOREST FOR THE TREES: ELEMENTARY STEM ENVIRONMENTS THAT NURTURE CREATIVITY AND INNOVATION

An Abstract of a Dissertation

Submitted

in Partial Fulfillment

of the Requirements of the Degree

Doctor of Education

Approved:

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December, 2019
ABSTRACT

This study examined creativity in schools through the lens of nine rural Midwestern public school fifth grade students in a student-centered, inquiry-based science classroom within a STEM Framework. Previous literature suggesting the importance of nurturing creativity in schools (Florida, 2004; Executive Office of the President, 2018; K. H. Kim, 2016; Csikszentmihalyi, 1999) inspired the purpose for this dissertation. What is missing is the perspective of creative youth. Phenomenology as a research method is a “systematic attempt to uncover and describe the structures, the internal meaning structures, of lived experiences” (van Manen, 2016, p. 10). Through student voices, this qualitative study sought to illuminate students’ lived experiences.

The researcher selected nine students for this study based on their demonstration of creativity within a project involving invention and innovation. Data was collected to determine answers to the following questions:

Research Question 1: How do students perceive creativity in a student-centered, inquiry-based science classroom within a STEM Framework?

Research Question 2: What do students value about the experiences within a STEM Framework in a student-centered, inquiry-based science classroom?

Research Question 3: What factors supported their experiences?

Data was collected through in-depth student interviews, observations, photos, and student writing. Data was analyzed using the constant comparative methodology informed by the work of Glaser and Strauss (1967) to capture actual lived experiences of students immersed in a science classroom with a STEM Framework.
Findings suggest student perceptions of creativity intersect with the definitions found in the literature on creativity (Csikszentmihalyi, 1996; Said-Metwaly, Kyndt, & Van den Noortgate, 2017; Torrance, 1970) as well as the researcher’s perceptions of creativity. Authentic learning and opportunities to collaborate with others were highly valued by the students, and relevance, relationships, and feedback were instrumental in establishing that value. Student explanations of what they valued in their experiences in a science classroom within a STEM Framework contained wording that closely aligned with definitions of creativity. This study is significant for teachers with goals to nurture creativity and innovation within the context of their classrooms, as well as administrators and policymakers who seek to support these teachers.
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Approved:

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Dr. Mason Kuhn, Committee Member

Dr. Scott Greenhalgh, Committee Member

Lisa Jo Chizek
University of Northern Iowa
December, 2019
DEDICATION

To my wonderful husband, Dave, who gives me continuous support and encouragement and also makes me laugh when I need to laugh the most. Thank you for always believing in me. You are the wind beneath my wings, and I wouldn’t be here without you. I love you.

To my incredible children, Malynda, Daniel, Nicholas, and Kelly, and my bonus daughter, Angel. You all do such amazing things and you inspire me to want to do more and live my life to the fullest! Thank you for being part of my life. Keep following your dreams. I love you!

To Mason and Élodie (and all of my future grandchildren). You bring more joy and love into my life, and I feel blessed. You make my work important. Keep following your dreams. You are amazing, and I love you.

To my parents, Joan and Roger, thank you for taking me camping, hiking and fishing when I was young. Thank you for your support. I love you.

To my friends. Thank you for believing in me!

To my students. Your enthusiasm inspires me. Thank you.
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CHAPTER 1
INTRODUCTION

Creativity and innovation are important in STEM careers. STEM careers require creative people who can come up with original ideas and solve complex problems. Employers are looking to schools for assistance in developing a creative and productive workforce. It is essential that employers and schools agree on how to define, identify, and nurture creativity.

Importance of Creativity in American Society

In 2004, the Harvard Business Review published an article entitled, “America’s Looming Creativity Crisis” (Florida). The article cautioned how America needed creative people to develop new ideas and solve complex problems. The author suggested state governments should plan long-term for the economy by investing in foundations that nurture creativity. “The U.S. must begin to think of creativity as a ‘common good’ like liberty or security. It is something essential that belongs to everyone and must always be nourished, renewed, and maintained – or else it will slip away” (Florida, 2004, p. 136). More recently, the Executive Office of the President released the report, Charting a Course for Success: America’s Strategy for STEM Education (2018). Priorities in this report included an education system that nurtures creativity and innovative problem solving. The report stressed the importance of problem finding and innovation skills as American society needs people who are able to look at problems from many directions in order to effectively solve them. The authors of the report believe skills within STEM are universal, as they help people make more informed personal decisions as well as prepare
for the challenges of an ever-changing world. The report also states STEM education should be accessible to all students. Currently, American schools are focused on scores on standardized tests and may be producing standardized, rather than creative thinking. K. H. Kim (2016) suggests “If America’s parenting and educational system continuously condition children to think un-creatively, employers will struggle to hire creative individuals to solve real-world problems and create new opportunities” (p. 19).

Company Work Environments Engineered for Creativity

Companies that excel because of creative and innovative products and approaches design a work environment that nurtures creativity and innovation. Two such companies are the Innovation Design Engineering Organization (IDEO) and Google. Their leaders suggest several components for supporting creativity and innovation.

The creative environment at IDEO. Kelley, Brown, and Bennett (2013), leaders of the innovative design company IDEO, listed elements considered essential for nurturing creativity. These elements included: diversity, passion, positive relationships, flexibility, responsibility, and dismissing a one-size-fits-all pathway to success. Kelley et al. (2013) wanted diversity within their employees who felt passionate about tasks and believed their work would help the world.

Collaboration within diverse teams is essential in order to capitalize on a variety of perspectives dealing with a similar problem. To increase the effectiveness of collaboration, IDEO leaders emphasize building relationships among employees, clients, and the community. The workplace should have a positive culture where people listen to each other, give honest feedback, reflect, share accomplishments, learn from mistakes,
and work together. IDEO’s leaders acknowledge that everyone’s journey at IDEO is different, and they try to provide support, structure, and management.

**The creative environment at Google.** Google, another innovative company, attributes the company’s success to similar elements. Innovation requires risk. At Google, mistakes are expected and seen as opportunities to learn. Google’s leaders value creativity and diverse collaborations within their company and promote strong relationships among their employees. J. Kim (2013) shared how the leaders at Google value creativity in their decision making framework. Decisions at Google are made through discussions using data. The goal is not for unanimous decisions, but rather deep discussions that lead to a decision that helps everyone understand and accept it. Employees are “kept in the loop” and are welcome to question and discuss. Google has a positive atmosphere because of their openness and collaboration (J. Kim, 2013).

**Definition of Creativity**

Studies on creativity and how to support it in schools are important because creativity is what helps us deal with a constantly changing world in useful ways (Sternberg & Lubart, 1996). In order to proceed with these studies, creativity needs to be defined; however, research suggests creativity is an abstract concept that is difficult to define. Nevertheless, some similarities in research definitions of creativity were found.

In their synthesis of literature on creativity, Said-Metwaly et al. (2017) found that studies were diverse in their definitions of creativity. Some studies avoided the difficulties in defining creativity while others defined it in similar ways: process, characteristics of creative people, creative production, and supportive environment. Lau,
Hui, and Ng (2004) similarly suggested the reality of research on creativity illustrated how attempts to define creativity were continuous and difficult to do.

Defining Creativity through Products

One manner of defining creativity is through the analysis of products. The uniqueness and usefulness of a product is often valued as creative. K. H. Kim (2016) informs us “Creativity is making something unique and useful” (p. 32). Csikszentmihalyi (1996) suggested creativity is something new that is valuable and accepted. Sternberg (1999) and Runco (2014) shared similar definitions, suggesting creativity is creating original and useful work. Acar, Burnett, and Cabra (2017) conducted a study looking at which of four factors were most important for identifying creativity: originality, value, surprise, or aesthetics. They found participants chose originality as the primary factor, then surprise or unexpectedness of product or idea, and finally, value as a third factor in identifying creativity.

Creativity is often recognized and valued in a person’s hobbies. A study at Michigan State University connected creativity and STEM finding highly-successful STEM professionals were significantly more likely to have had creative hobbies throughout their lives than other STEM professionals (Root-Bernstein, 2015). The authors suggested creativity may be a way for learning to develop better solutions to difficult problems because creativity allows people to look at things differently and recognize similarities in dissimilarities (Root-Bernstein, 2015).
Defining Creativity through Behaviors and Traits

Another manner of defining creativity is analyzing the behaviors and traits of people considered to be creative. Torrance (1970) suggested that creative people were curious and always asking questions. They liked challenges, were able to look at problems differently, found the real problem, and became totally immersed in their work.

Csikszentmihalyi (1988) conducted a synthesis of research, sharing many important insights about creativity. Most importantly, creative thinking changed the way people thought about problems, helped them pose better questions, and enabled them to find new, more important problems to solve. Creative people spent the time needed to determine the real problem before the problem could be solved. Additionally, creative problem solving involved more than just following a step-by-step procedure. Creative people were more open-minded and willing to take their time. People who were creative were also flexible in thinking of alternate possibilities rather than being satisfied with the status-quo or easy answers. Their thinking was not linear following a rote problem solving process.

Measurement of Creativity

Creativity is important for personal decision making, career success, and solving global problems. Because of its importance, research about creativity and how to improve and measure its development is essential (Said-Metwaly et al., 2017).

A review of 152 quantitative studies suggested researchers base their measurement of creativity on their definition of creativity (Said-Metwaly et al., 2017). Measuring the environment was done the least and this research synthesis suggested that
the construct of environment needs to be defined better before it can be successfully measured (Said-Metwaly et al., 2017). The review also suggested that since environments that support creativity include factors such as the socio-moral, then measurement of creativity needs to take all factors into consideration. While most instruments measure the process of creativity, including tests evaluating divergent thinking, some researchers questioned whether divergent thinking tests validly measure creativity. Another study suggested research on creativity in schools has centered on how teachers can enhance creativity in the classroom as determined by quantitative studies using tasks to measure problem solving abilities or tests measuring divergent thinking (Long, 2014). Self-reporting techniques have been used to measure characteristics of creative people. However, self-reports could be biased for various reasons due to intentional and unintentional distortions of answers. Evaluating products has also been used as a measurement of creativity, but research suggested these measurements may be subjective due to evaluations done by people of different experience (Said-Metwaly et al., 2017). The authors also suggested different measurements could be used together to better measure and enhance our understanding of the difficult-to-define concept of creativity.

**The Importance (or Unimportance) of Creativity in American Schools**

The United States is demanding a workforce that is creative, innovative, and STEM literate because our country needs people who can develop new ideas, make informed decisions, and solve complex problems. To meet these demands we need to think about how schools can better support student learning. It makes sense that public
schools in the United States provide a learning environment that nurtures creativity and innovation.

**STEM Education and Creativity**

In a recent report from the Executive Office of the President (2018), *Charting a Course for Success: America’s Strategy for STEM Education*, the authors recognize the importance of creativity in STEM education: “In an increasingly competitive global economy, STEM education that emphasizes convergent processes and promotes problem finding and creativity is needed to accelerate innovation and entrepreneurship” (p. 16). In their article on STEM education, Tsupros, Kohler, and Hallinen (2009) agree with the importance of developing skills in solving complex problems, writing how STEM education involves integrated and authentic learning experiences. Aligning with the *Charting a Course for Success* report (Executive Office of the President, 2018), Project-Based Learning (PBL) uses well-planned authentic learning experiences for students to work collaboratively to creatively solve interdisciplinary, real-world problems (Boss, Larmer, & Mergendoller, 2012). The findings from a study examining the impact of PBL professional development (Hixson, Ravitz, & Whisman, 2012) suggest teachers who use PBL are more likely to help their students develop creative and innovative thinking when compared to students whose teachers do not use PBL; this includes differences in how students look at problems while generating unique ideas to solve those problems.

**Considering Educational Environments for Creativity**

Csikszentmihalyi (1999) encouraged schools to consider the experiences they provide students. He recommended that young people be given opportunities to immerse
themselves in learning experiences that are meaningful and bring them joy. Research suggests these opportunities help students feel their work has purpose and meaning (Ilies et al., 2017). The literature additionally informs us that when people are able to absorb themselves in work that challenges them and is meaningful to them, they feel more satisfaction with their work. Happiness is associated with creativity and people who are happy are more creative and thus more likely to be independent thinkers who can think of alternative ways to solve problems (Pannells & Claxton, 2008).

**A Place for Creativity in American Schools**

According to Arnett’s (2018) report of the Reagan Foundation’s first summit on education, national education leaders stated the role of American schools is to emphasize literacy, mathematics, and citizenship. Additionally, Arnett (2018) stated that leaders considered interdisciplinary opportunities for students to communicate, collaborate, and be creative as essential. Arnett (2018) continued to report that U.S. Secretary of Education Betsy DeVos stated creativity is important while Condoleeza Rice, former U.S. Secretary of State and current Stanford University professor, indicated more than one pathway to success should be offered in schools. Despite these intentions, creativity may be shoved aside in service of test scores.

**Creativity in the Era of Standardized Testing**

Csikszentmihalyi (1996) cautioned schools not to focus only on testing. He suggested, “When school budgets tighten and test scores wobble, more and more schools opt for dispensing with frills” (p. 12). Csikszentmihalyi’s concern is that when school administrators become anxious about test scores they often narrowly sharpen their focus
on what they consider the basics, eliminating the essence of what allows students to develop original and creative thinking. Despite this caution, the 2001 legislation of No Child Left Behind (No Child Left Behind [NCLB], 2002) helped usher in the era of standardized testing in American public schools.

Researchers investigated the effects of this focus on standardized testing. Au (2007) found high-stakes testing led many teachers to concentrate on low-level, superficial instructional practices, essentially teaching to the tests. Lobascher (2011) supported this, suggesting many public school classroom environments have been redesigned to accommodate a narrow and sharpened focus on literacy achievement measured by standardized tests. Kohn (2012) discussed how improved test scores do not necessarily indicate improved teaching and learning. In fact, improved test scores may mean schools were teaching to the test and/or “gaming” the test. Some suggest public school is becoming a “test prep factory” (Kohn, 2012, p. 90).

Henriksen and Mishra (2015) found creativity and innovation were constrained in schools due to high-stakes testing, accountability, and education policy. Teachers reported they did not feel they were working in environments where they felt safe to be creative. K. H. Kim (2011) suggested increased rote learning, thought to help students perform better on high-stakes testing, was eliminating creativity in education. Watkins (2012) supported this, informing us children’s curiosity and questioning “is harnessed by the demands of standardized tests” (p. 30). Kohn (2012) agreed and suggested a problem being created in public schools through high-stakes testing is that conformity has become more important than curiosity.
An additional concern is when educators do not take the time to see the ramification of their choices. When teachers fall in line with what is promoted as being best for students, they end up helping promote the high-stakes testing agenda. Lipman (2012) informs us of the consequences of these choices:

I refer to the processes through which dominant social forces bring under their leadership sectors of other classes and social groups by constructing a common sense that resonates with lived experiences and by disarticulating elements of liberatory social ideologies to their agendas. Subaltern groups also exercise agency in this process, tactically aligning themselves with aspects of dominant agendas in an effort to “make do” within the constraints of the present situation. (p. 35)

Thus, school environments become dull and detrimental to what society and students need to support the development of creative problem solvers and life-long learners. It is essential to reexamine what is necessary to ensure that children in American public schools are immersed in educational environments that not only provide meaningful contexts to learn to read and write but also to nurture creativity and innovation to benefit the changing needs of American society.
CHAPTER 2
REVIEW OF LITERATURE

A literature review was conducted to determine what is necessary to ensure that children in American public schools are immersed in educational environments that not only provide meaningful contexts to learn to read and write but also to nurture creativity and innovation to benefit the changing needs of American society. The review of literature elicited five common themes of influence on the development of creativity. These themes included: 1) teaching practices; 2) types of learning opportunities; 3) feedback; 4) relationships; and 5) the environment.

Teaching Practices

One common theme found influencing creativity in schools was teaching practices. A teacher’s practice either hinders or nurtures the development of creativity. Teaching practices emphasizing memorization or evaluation negatively impact creativity. Torrance and Harmon (1961) recruited 115 university students in a personality development and mental hygiene course at a Midwestern university to participate in their study looking at tasks teachers assign that promote creative thinking. Participants were alphabetically assigned to read assignments with one of three specific purposes: 1) memorization of information; 2) evaluation of information; or 3) considering all the ways the information could be used. After reading the material, participants were tested on the reading. They found that participants who considered all the ways the information could be used as they read the assignment scored higher on the creative applications of the tests.
Teaching practices that view creativity existing outside of the regular classroom hinder the development of creativity. Patston, Cropley, Marrone, and Kaufman (2018) conducted a study involving over 2,400 students and teachers in six countries to examine teachers’ implicit bias that creativity is only found in art. Participants completed an online survey measuring both an arts bias in creativity as well as participants’ perception of their own creativity. Findings suggested that teachers who are uncertain about the definition of creativity and how it might be incorporated into their classrooms are more likely to block efforts to implement creativity within their classrooms.

de Souza Fleith (2000) found drill and practice tasks inhibited the development of creativity. de Souza Fleith’s qualitative study looking at factors that obstruct the development of creativity found that controlling teachers and a requirement to have the right answer inhibited creativity. While right answers are needed in standardized testing, highly effective teachers referenced the accountability of high-stakes testing as a hindrance to innovative teaching that nurtures creativity (Henriksen & Mishra, 2015). Henriksen and Mishra (2015) designed a qualitative descriptive study to determine how highly effective teachers embraced creativity. They selected eight highly effective teachers who were recent finalists or recipients of the National Teacher of the Year Award and conducted in-depth interviews to determine how these teachers defined creativity, how they nurtured creativity in their classrooms, and how their personal creativity connected with their practices in their classrooms. All of the teachers considered creativity in the context of their teaching practice. Creativity was thought as something novel and engaging for their students, something that had no single right
answer, or something that allowed their students to be innovative in their work. Authentic and cross-curricular teaching was viewed as important for nurturing creativity. The teachers stressed how essential it was for students to feel safe in making mistakes, indicating the importance of the learning environment.

Teaching practices that employ student-centered learning were found to support the development of creativity in several studies. A survey of experts in creativity suggested student-centered learning that provides students opportunities to pursue their own interests was essential for enhancing creativity (de Souza Fleith, 2000). Jeffrey and Craft (2004) agreed, suggesting teaching practices that allowed children to ask questions, investigate, and solve problems that interested them supported the development of creativity. In a complex study using multiple research sites and researchers, Jeffrey (2006) looked for common features of creative teaching and learning. Participants in the study included a range of ages, from early learners to adult learners. Researchers used a common lens to examine what was happening at each site and then sorted these events into broad themes and categories. Findings showed relevant and student-centered teaching practices, such as students asking questions that interested them and then investigating to answer their own questions, were important in nurturing creativity. Connections to outside experts were also emphasized.

Teaching practices within a school culture impact the development of creativity. Basancon and Lubart (2007) developed a study assessing different tasks to investigate whether students in traditional schools (where the teacher asks the questions, decides what needs to be learned, and how it will be learned) or non-traditional schools (where
learning is student-directed) scored higher in creativity tasks. Two hundred eleven children from both traditional and non-traditional schools were assessed on divergent and integrative tasks over two years. Children were assessed on the tasks individually and five judges evaluated each task on a seven-point Likert scale. The study found that students in non-traditional, student-centered schools performed more creatively on tasks than students in traditional, teacher-directed schools.

Teaching practices that involve creative problem solving but lack congruence with the assessments used squelch creativity. Guilford (1950) noted:

We all know teachers who pride themselves on teaching students to think and yet who give examinations that are entirely a matter of knowledge of facts….Let us remember, too, that the kinds of examinations we give really set the objectives for the students, no matter what objectives we may have stated. (p. 448)

Teachers who want to nurture creative problem solving in their students need to consider the psychological impact of using assessments that emphasize only knowledge.

Types of Learning Opportunities

Another theme of influence on the development of creativity in schools was the type of learning opportunities offered to students. de Souza Fleith (2000) found opportunities for unstructured time were perceived by both students and teachers as necessary to develop creativity. These opportunities allowed students time to focus and work on problems they found meaningful. Scheduling relevant field trips and bringing in outside experts related to students’ work also influenced the development of creativity.

Opportunities for autonomous learning influence the development of creativity. Using a data set from a 1971 Early Years school, Jeffrey and Craft (2004) looked for major themes in creativity in a primary school. The data for this study included
interviews with teachers, parents, visitors, staff, and students; artifact collections; and photographs. Student-centered activities which were meaningful and encouraged the children to take control and work innovatively were important for developing creativity. Later studies agreed. Jeffrey (2006) suggested authentic learning in the process and production of creative products was necessary for creative learning. Henriksen and Mishra (2015) also found that real-world and integrated learning opportunities promoted creativity.

Opportunities to engage with open-ended materials influence the development of creativity. Lasky and Yoon (2011) considered creativity as requiring more than just a mental act but also requiring construction of concrete ideas and objects. They conducted a study with four instructors of an after-school program incorporating engineering design projects (Lasky & Yoon, 2011). Data was collected in the forms of interviews and observations over three semesters. Findings suggested instructors with the least understanding of creativity as a process that can be learned were least able to create a space for creativity in their classroom.

Feedback

Supportive and specific feedback is a factor that influences the development of creativity. In the business sector, Steelman, Levy, and Snell (2004) suggested organizations develop an environment where employees feel safe to freely exchange feedback with others. Ashford (1986) supported this finding and suggested organizations work to remove concerns employees have that their images will be affected by seeking feedback. De Stobbeleir, Ashford, and Buyens (2011) used data collected from a larger
study of 456 supervisor-subordinate pairs from four large consulting companies, looking at whether seeking feedback enhanced creative performance. Study participants completed two online surveys. Results showed that feedback seeking was significantly related to creative performance (De Stobbeleir et al., 2011). Findings also indicated seeking feedback from a variety of sources was beneficial. The study suggested organizations may want to support their employees in seeking broad and frequent feedback on their performances.

Like business, schools can consider their quality of feedback in their efforts to nurture creativity. K. H. Kim (2011) informs us children need adults to seriously listen to them and their ideas. Learning to self-evaluate and evaluate peers is another necessary step in the creative process. Children also need to learn to listen to and use constructive criticism in their work. Hattie and Timperley (2007) conducted a synthesis of meta-analyses on feedback. Findings suggested that giving information concerning a performance or understanding was considered feedback. Additionally, in order for feedback to be instructive, the information needs to be specific. Feedback can be accepted as given, modified for use, or rejected.

Feedback is considered high-quality when it is specific and centered on effort and perseverance, as well as understanding (Wilson, Pianta, & Stuhlman, 2007). Feedback is only effective within a supportive environment where employees and students feel safe to freely exchange ideas (Steelman et al., 2004).

Jonsson (2012) also linked positive environment with feedback. A literature review of 103 studies on how students use feedback found feedback needed to be useful,
timely, specific, and individualized. However, feedback should not tell students what to do in a step-by-step manner because that does not lead to productive learning. Feedback should not be given in an authoritative manner and that in order for feedback to be worthwhile, research suggests it needs to be used by students. Effective feedback demands a trusting and supportive environment. Just as organizations foster creativity when they develop an environment where employees feel safe to freely exchange feedback with others (Steelman et al., 2004), schools can foster creativity when they create an environment where students feel safe to freely exchange feedback with their peers and teachers.

**Relationships and Creativity**

Businesses that thrive on creative problem solving acknowledge the importance of building relationships. Amabile, Fisher, and Pillemer (2014) surveyed 47 employees at one IDEO location to learn who they seek for help and why. They used the data to map the relationships. Results of the mapping suggested people looked for help more often from people they trusted over people they considered more competent. This suggested that people need to feel safe talking with others about problems or mistakes because they feel vulnerable when asking for help.

E. Paul Torrance, “recognized as the most prolific and internationally recognized education psychologist with a research emphasis on creativity” (Grantham, 2013, p. 518) discussed how essential positive adult student interactions in responsive classroom environments are for supporting creativity. Responsiveness includes honoring children’s questions and curiosity, allowing children to immerse themselves in their work, and
honoring student interests, autonomy, and self-direction. “Creative ways of learning, in fact, call for the most sensitive kind of guidance and direction possible. They call for intense listening and observing, and for giving the kind of guidance that will make all honest efforts to learn worthwhile enough to sustain motivation and to keep the learning process going” (Torrance, 1970, p. 10). He suggested creativity was inhibited in environments that teachers seem to find more efficient but are teacher-directed and controlled.

More recent studies of creativity in schools also find relationships to be essential for nurturing creativity. Poor relationships are formed when creativity is misunderstood. In a study looking specifically at teacher attitudes toward creative children, Scott (1999) surveyed 144 elementary teachers from California and 133 Kansas State undergraduate pre-service teaching students. The surveys described four elementary students and then had participants tell how they perceived each student. An ANOVA was done and the data found children who were described as highly creative were considered significantly more disruptive. This agreed with the earlier findings of Torrance (1970) that suggested teachers perceive creative students as disruptive. These attitudes could adversely affect creativity in the classroom.

Positive teacher-student relationships are essential in nurturing creativity. It is important for adults to listen to children. Children need to feel their ideas are important and that adults care about them and their thinking. Real adult connections with students are a valuable element for validating student work (Camino, 2000; K. H. Kim, 2011).
de Souza Fleith (2000) used a qualitative research method to study factors that enhance or inhibit creative development in classrooms. Three different groups of participants were involved in this study. Seven third and fourth grade classroom teachers were individually interviewed, data was gathered from 31 third and fourth grade students participating in focus groups, and seven experts in creativity responded to questionnaires. Data from all participants was coded and put into categories to look for relationships. Findings showed that both experts and teachers perceived positive teacher attitudes enhanced the development of creativity. Students also suggested relationships with teachers and peers were important to them.

Fawcett and Hay (2004) examined actions of adults that support creativity. They completed two case studies of the 5x5x5 = Creativity in the Early Years project studying the collaboration between the adults and children. They found when adults attended to and supported student interests there was more engagement in creative processes and products, which suggested adult and child relationships were very important. Jeffrey (2006) and Jeffrey and Craft (2004) also found positive teacher attitudes and relationships important for creative teaching and learning.

Berghetto (2006) surveyed 117 pre-service teachers enrolled in an educational psychology college course to find out their perceptions of the importance of creativity, their past learning experiences, and their perceived ability to promote creativity. He found that pre-service teachers who felt their creativity was not nurtured in their past schooling indicated they were committed to promoting creativity and also felt capable of promoting creativity. He also found that pre-service teachers who were satisfied with
their past schooling experiences were not as committed to promoting creativity in their future classrooms.

**Creativity and the Environment**

Torrance (1970) pointed to the importance of environments in his work in creativity. Environments that are flexible with time and allow children to completely engage in investigations interesting to them were found important to the development of creativity. Torrance suggested that learning in teacher-directed environments promoted lower levels of thinking, while environments that honored student questions and testing of ideas promoted higher levels of thinking.

Over thirty years ago, Csikszentmihalyi (1988) described environments that nurture creativity. Conducting a synthesis of research connecting creativity, motivation, and learning, Csikszentmihalyi discussed several significant insights. Creative problem solving is more than just following a rote procedure and students needed to be open-minded and willing to take their time. Students also need to be flexible in considering all possibilities rather than satisfied with the status-quo or easy answers. Intrinsic motivation and enjoyment in the discovery process is a part of creative problem solving. Emotions and motivation influence thinking, and motivation is essential. Ideally, students need to be passionately curious about a topic and able to overcome opposing demands for time and resources to persist in the problem solving process. An effective environment for creative problem solving considers factors that involve motivation and an intrinsic desire to learn. Csikszentmihalyi (1996) suggested, “It is easier to enhance creativity by changing conditions in the environment than by trying to make people think more
creatively” (p. 1). Additionally, he indicated environments that nurture creativity meet the needs of the individual where they feel safe and in charge of their endeavors. Rigid teacher-directed environments that control students and their thinking impede the development of creativity (Csikszentmihalyi, 1996). He also informs us “Even the most abstract mind is affected by the surroundings of the body. No one is immune to the impressions that impinge on the senses from the outside” (p. 127). He asserts “the spatiotemporal context in which creative persons live has consequences that often go unnoticed” (p. 127).

As Csikszentmihalyi was researching the importance of the environment in creativity, Dweck and Leggett (1988) were researching the effect of the learning environment on persistence, a trait necessary for creative work. Dweck and Leggett studied upper elementary students to determine patterns between children who give up and children who persist. They used interviews and observations to investigate how children approached and changed methods for problems they had to solve. Dweck and Leggett (1988) identified two different mindsets or purposes for working: the purpose of performance and the purpose of learning. In the purpose of performance mindset, students are externally motivated, seek validation that their abilities are good enough, and want to document performance. These students believe abilities are fixed and cannot be improved. If these students have to work hard to perform, then they believe they lack ability. Mistakes and failure are viewed as shameful. Errors threaten self-esteem, and students discontinue and devalue learning. In contrast, with the purpose for learning mindset, students are internally motivated and want to learn the material or the skill.
These students desire to develop abilities and believe abilities can be changed or improved. Working hard is a way to learn more, and failure suggests the need for greater effort. Students who work to learn continue to put forth effort even in challenging situations where failure may occur. Thus, in order to help students acquire the qualities of persistence, desire for challenge, and intellectual risk taking, a work to learn model needs to be supported.

Teachers who are focused on student performance may want to consider that an environment that is designed to encourage creativity increases performance. Sternberg and Lubart (1996) conducted research looking at the correlation between the classroom environment and performance; 199 high school students participated in the study in a psychology course. Students who scored high in creative abilities were placed in two different classroom environments: an environment that supported creativity and encouraged students to design their own experiments to test their ideas, or an environment that did not encourage creativity. They found students who worked in an environment that encouraged creativity performed better in the course than students who worked in an environment that did not support creativity.

Despite the research of Csikszentmihalyi (1988) and Dweck and Leggett (1988) on the importance of environment, creativity in children has declined. K. H. Kim (2011) looked at data sets from 40 years of Torrance Tests of Creative Thinking and found a decline in creative thinking in all ages. The decline in creativity for young children was especially problematic because early childhood is a foundational time for developing beginning creativity skills. K. H. Kim and others began to again call attention to the
importance of environment in stimulating creativity starting with the need for children to experience a safe and accepting environment (2011). Davies et al. (2013) agreed in their review of 32 studies that used interviews, observations, artifact collections, attitude surveys, and test scores to identify environments that nurture creativity in children. The review suggested the learning environment is more important than the physical environment. The learning environment includes social factors and pedagogy different than the traditional practice. Environments that enhance creativity need to support student risk taking. In such environments, students do not need to be concerned with having the right answer; they have flexibility with time, are allowed to ask their own questions, and have positive relationships between their peers and teachers.

Student engagement is responsive to the environment. From birth, young people are intrinsically motivated to explore and learn about their world, and this innate disposition must be supported, and not hindered or reduced. Eccles and Wigfield (2001) as well as Ryan and Deci (2000) suggest several things that harm intrinsic motivation. External rewards, assessments, deadlines, and outside pressure decrease intrinsic motivation. Controlling environments subdue motivation and are less effective in helping children learn (Eccles & Wigfield, 2001). People who are authentically motivated demonstrate passion, perseverance, better performance, creativity, more vigor, and are generally happier (Ryan & Deci, 2000). Rathunde and Csikszentmihalyi (2005) support this, suggesting that students in traditional classrooms are more focused on grades and are not as intrinsically motivated or interested in their work.
Daniels and Arapostathis (2005) studied four randomly selected boys who were reluctant learners from an alternative high school, interested in the boys’ perceptions of what they wanted from their education. Results showed that academic achievement was challenging to separate from student engagement. Students were more engaged if they enjoyed the content. However, the boys enjoyed tasks and had high abilities in activities not valued by the school, which led to less engagement. Autonomy, self-efficacy, and meaning were also important for increasing student engagement. Students wanted honest feedback from teachers, and students indicated they wanted assignments to have value. Daniels and Arapostathis (2005) concluded extrinsic rewards devalued the intrinsic merit of engaging in learning. Additionally, research suggests teachers need to allow students to work through frustration to help students learn to take risks. Research also suggests teachers need to learn to balance between too much support and not enough support. This will allow teachers to provide learning experiences that challenge and help students build skills to be successful. Students can then transfer this confidence and success into other areas.

Students in supportive environments where they received high-quality feedback demonstrated more engagement. Environments are crucially linked with feedback. Using data from previous studies, Wilson et al. (2007) conducted a study of children in early grades within 700 schools throughout 32 states. Using a multi-informant longitudinal design, trained observers rated behaviors of the children and also the classroom environment. Findings suggested a classroom is considered to have a positive environment when the teacher demonstrates positive feelings for the students including
enthusiasm and respect, and a positive environment is highly correlated to teacher sensitivity.

Fredericks, Blumenfeld, and Paris (2004) suggest that since the environment is an important ingredient in student engagement, environments that nurture creative problem solving must be seriously considered. Environments that support autonomy, competence, choice, and authenticity enhance the growth of motivation, curiosity, persistence, and the passion for challenge. These are essential qualities for students to be able to think, reason, and be creative problem solvers, enjoy work, and help move the world forward (Abuhamdeh & Csikszentmihalyi, 2012; Black & Deci, 2000; Bloom & Unterman, 2013; Csikszentmihalyi, 1988; Cleary & Zimmerman, 2004; Eccles & Wigfield, 2001; Jang, Reeve, & Deci, 2010; Reeve & Jang, 2006; Ryan & Deci, 2000; Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003).

**Gap in Literature**

The wide scope of literature about research on creativity in schools suggests many pieces important for nurturing creativity in schools. Interviews have been conducted with teachers and experts in creativity to determine their understanding of creativity in teaching and learning. However, no studies were found examining creativity in schools through the lens of young students. Such a study may reveal what experiences students value as well as what students perceive as nurturing their creative problem solving and innovative thinking.
Research Questions for this Study

This study examined creativity through the lens of fifth grade students in a student-centered, inquiry-based classroom within a STEM (Science, Technology, Engineering and Math) Framework. Using student voices, this study learned what these students perceived as important in their development as creative and innovative thinkers in a science classroom within a STEM Framework. The study was guided by the following questions:

Research Question 1: How do students perceive creativity in a student-centered, inquiry-based science classroom within a STEM Framework?

Research Question 2: What do students value about the experiences within a STEM Framework in a student-centered, inquiry-based science classroom?

Research Question 3: What factors supported their experiences?
CHAPTER 3

METHODOLOGY

In the previous chapters the importance of creativity was discussed, as well as definitions and methods of measuring creativity, teaching practices, learning environments, and opportunities that nurture creative problem solving and innovation. The review of literature demonstrated a lack of studies examining creativity in schools through the lens of fifth grade students in a student-centered, inquiry-based science classroom within a STEM Framework. In this chapter, the researcher will focus on the methodology used to guide this research. Using a constant comparative analysis and a thick description of the academic lives of the participants, the researcher focused on identifying how graders perceive creativity, what they value in STEM experiences specifically designed to nurture creativity, and what factors supported their creative behaviors within these STEM experiences.

Phenomenology Design

The literature on creativity punctuated the importance of environment on its development (Sternberg & Lubart, 1996; Davies et al., 2013; Csikszentmihalyi, 1996). The researcher employed a qualitative research method informed by phenomenological perspectives to determine: 1) students’ perceptions of creativity, 2) what they value about their experiences in a hands-on, inquiry-based science classroom within a STEM Framework that calls for creativity, and 3) their perception of what supported their experiences. Phenomenology is a qualitative research method that learns from lived experiences and “aims at gaining a deeper understanding of the nature or meaning of our
everyday experiences” (van Manen, 2016, p. 9). There is not one set way to do phenomenological research (Hycner, 1985), but what identifies phenomenology as a method is its “systematic attempt to uncover and describe the structures, the internal meaning structures, of lived experiences” (van Manen, 2016, p. 10). Phenomenology does not serve to create a theory about the world, but assists us in gaining insights into the essence of lived experiences of the world. Polkinghorne (1989) informs us, “The locus of phenomenological research is human experience” (p. 45). The locus of this study is students’ lived experiences in a hands-on, inquiry-based science classroom designed to support creativity and innovative thinking. To accomplish this, the researcher conducted a systematic attempt to uncover and describe the internal meaning structures of her rural Midwest fifth grade students’ lived experiences as creative science students. The researcher drew upon Csikszentmihalyi’s study that used in-depth analysis of interviews conducted with creative individuals to determine what creative people are like, how the creative process works, and what conditions encourage or hinder the generation of original ideas (1996). The researcher used in-depth analysis of interviews, observations, photos of students working and student work, and student writings to determine fifth grade students’ perceptions of creativity, what experiences they value and what nurtures their experiences.

A study informed by phenomenological research perspectives was used to seek a deeper understanding of the essence of students’ lived experiences in a hands-on, inquiry-based science classroom designed to support creativity and innovative thinking. To support this deep understanding, the researcher constructed a thick description of the
school context of the fifth grade students. Glaser and Strauss (1967) was used as a guide for the design of this qualitative study. The researcher implemented an inductive strategy to discover concepts and hypotheses through constant comparative analysis. The researcher listened to recorded interviews, read transcripts of the interviews and observation notes, and looked at student artifacts, constantly comparing emerging data for answers to the research questions.

**Site Selection and Setting**

Phenomenology requires the researcher to develop a “systematic attempt to uncover and describe the structures, the internal meaning structures, of lived experiences” (van Manen, 2016, p. 10). Students’ lived experiences are impacted by their geographical, cultural, and social contexts. To better understand these contexts of the students and teacher researcher, a thick description is provided of the school district and the context of the fifth grade student schedule classroom and the context of the fifth graders within the science classroom.

**District Information**

The site for this research was in a small, rural, Midwestern public school district with an enrollment that had been declining. The district had an enrollment of 442 students from Preschool through Grade 12 housed in one building. There were a total of 223 elementary students. The majority of students were Caucasian with a small number of mixed ethnicities. District Free and Reduced Lunch rate was 41%. The demographics of the district and elementary school were collected from the state Department of Education and can be seen in Table 1.
Table 1 Demographics of District and School

<table>
<thead>
<tr>
<th>Demographics</th>
<th>District</th>
<th>Elementary School</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Race/Ethnicity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>4.07%</td>
<td>4.04%</td>
</tr>
<tr>
<td>White</td>
<td>89.59%</td>
<td>89.00%</td>
</tr>
<tr>
<td>Black</td>
<td>0.45%</td>
<td>0.45%</td>
</tr>
<tr>
<td>Asian</td>
<td>0.50%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>0.23%</td>
<td>0.45%</td>
</tr>
<tr>
<td>2+ Races</td>
<td>5.20%</td>
<td>6.73%</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>45.25%</td>
<td>43.5%</td>
</tr>
<tr>
<td>Male</td>
<td>54.75%</td>
<td>56.5%</td>
</tr>
<tr>
<td><strong>Free and Reduced Lunch</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>40.95%</td>
<td>45.29%</td>
</tr>
</tbody>
</table>

Fifth Grade

Participants for this study were selected from the district’s fifth grade. These students had instruction in science and mathematics in the teacher researcher’s classroom and instruction in reading, writing, physical education, art, in other classrooms by other teachers.

Fifth grade instructional schedule. The 27 fifth grade students received instruction in art, physical education, music media, reading and writing, and mathematics and science from six different teachers in a given week. Three fifth grade students had IEPs. Two students left the classroom for extra literacy instruction the first part of the morning.

Fifth grade students changed classrooms during the school day for different subjects. Students began the day from 8:15 to 8:30 in a homeroom where attendance was taken and announcements made. The rest of this time was used for doing homework or
with a small group leaving for additional reading instruction. Science class followed in this same room from 8:30 to 9:15. After science class, all students moved to a different classroom and teacher for writing class from 9:15 to 10:00. After writing class, students moved to a different room for a special class that rotated among art, physical education, music, band, or another study hall. From 11:00 to 11:30, fifth graders went outside for recess and then went to lunch. Following lunch, students returned to their homeroom for 45 minutes of mathematics instruction. Students then moved to a different room and teacher for a 45 minute reading class. After math and reading, students had recess and then either social studies, specials, or study hall.

Fifth grade students were in the researcher’s classroom for homeroom, 45 minutes of science each day, 45 minutes of math each day, 45 minutes of social studies three times a week and 25 minutes of study hall four times a week. Students were with the researcher for a total of approximately 730 minutes a week with 225 of those minutes scheduled for science. Table 2 shows the weekly schedule for fifth grade students.
Table 2 Fifth Grade Class Schedule

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:15 - 8:30</td>
<td>Homeroom</td>
<td>Homeroom</td>
<td>Homeroom</td>
<td>Homeroom</td>
<td>Homeroom</td>
</tr>
<tr>
<td>8:30 - 9:15</td>
<td>Science</td>
<td>Science</td>
<td>Science</td>
<td>Science</td>
<td>Science</td>
</tr>
<tr>
<td>9:15 - 10:00</td>
<td>Writing</td>
<td>Writing</td>
<td>Writing</td>
<td>Writing</td>
<td>Writing</td>
</tr>
<tr>
<td>10:05 - 10:50</td>
<td>Study Hall/Guidance</td>
<td>SCh Art &amp; SCh PE</td>
<td>10:10-10:55 Band/Study Hall</td>
<td>SCh Art &amp; SCh PE</td>
<td>10:10-10:55 Band/Study Hall</td>
</tr>
<tr>
<td>10:56 - 11:26</td>
<td>Recess</td>
<td>Recess</td>
<td>Recess</td>
<td>Recess</td>
<td>Recess</td>
</tr>
<tr>
<td>11:31 - 11:51</td>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
</tr>
<tr>
<td>12:00 - 12:45</td>
<td>Reading</td>
<td>Math</td>
<td>Math</td>
<td>Math</td>
<td>Reading</td>
</tr>
<tr>
<td>12:45 - 1:30</td>
<td>Math</td>
<td>Reading</td>
<td>Reading</td>
<td>Reading</td>
<td>Math</td>
</tr>
<tr>
<td>1:30 - 1:45</td>
<td>Recess</td>
<td>Recess</td>
<td>Recess</td>
<td>Recess</td>
<td>Recess</td>
</tr>
<tr>
<td>1:50 - 2:35</td>
<td>Social Studies</td>
<td>2:00-2:30 Media</td>
<td>2:05-2:35 Music</td>
<td>Study Hall</td>
<td>2:05-2:35 Music</td>
</tr>
<tr>
<td>2:40 - 3:15</td>
<td>2:35-3:20 All SCh</td>
<td>SS/Study Hall</td>
<td>SS/Study Hall</td>
<td>SS/Study Hall</td>
<td>SS/Study Hall</td>
</tr>
<tr>
<td>3:15 - 3:20</td>
<td>PE Finishing</td>
<td>Get Ready to Go Home</td>
<td>Get Ready to Go Home</td>
<td>Get Ready to Go Home</td>
<td>Get Ready to Go Home</td>
</tr>
<tr>
<td>3:20</td>
<td>DISMISSAL</td>
<td>DISMISSAL</td>
<td>DISMISSAL</td>
<td>DISMISSAL</td>
<td>DISMISSAL</td>
</tr>
</tbody>
</table>

This study was designed based on the perspectives of phenomenological research practices, which uncovered the lived experiences of 27 students in a hands-on, inquiry-based science classroom within a STEM Framework. The lived experiences in the science classroom were designed by the researcher and influenced by the researcher’s theory of teaching and learning.

Through graduate work, the researcher began to question beliefs about teaching and learning and how a teacher’s perception of teaching and learning influences the structure of the classroom. She began to intentionally think about the purpose for what she was doing and how it impacted her students’ learning rather than just doing what has
always been done or what others were doing. This study acknowledges how the researcher’s perception of teaching and learning influenced the physical, socio-emotional, and intellectual educational environment of her classroom and how this may have impacted her students’ creativity and innovation.

**Physical environment of science classroom.** In the fifth grade science classroom, students sat at tables in groups of 3-4 students. There were eight student tables arranged in a way that made it easy for the teacher and students to move around the room. Students were assigned spots at a table to begin the day to help everyone get settled and to help with attendance taking. Students were free to choose different places to work within the classroom during science such as at a different table, sitting by counters, or sitting on the floor. Students would work in groups as well as individually. This physical environment was different from the other classrooms they experienced. In the other classroom for reading and writing instruction, the fifth graders were assigned seating in individual desks with the expectation they stay in their seat to do their work individually. Individual desks were what students experienced in previous years also.

**Socio-emotional environment of science classroom.** Taking time to develop the socio-emotional environment in a classroom is essential in order to build a community for learning. Students need to feel they belong and are heard (K. H. Kim, 2011). Positive relationships in the classroom help students feel safe to make mistakes, express themselves, and share their thinking. Learning environments should also allow opportunities for students to solve their own conflicts so they can practice those skills. In this environment, students feel valued as well as knowing they can learn from each other.
In science, it is important that students learn how to work well with others and to value each other’s contributions to their work.

At the beginning of the year, time was spent developing group work expectations. Students were assigned to write down what they believed was necessary for a group to work well together. Students wrote their ideas down as well as the purpose for each of their expectations. Once students completed writing, they gathered in small groups to share their ideas. In each small group, every child had the opportunity to share the expectations they came up with and the purpose for each. Once everyone in the group shared, the students were told to select the three most important expectations from all of the individual members’ lists along with the purpose for each expectation. Each small group took turns sharing with the whole class. A large group discussion then ensued to merge similar ideas or restate ideas, resulting in a list of student-designed group work expectations. While this process took time, students felt ownership of their expectations. They fully understood and valued the reasoning behind the expectations. Each student listed the expectations in their science notebooks for referral.

During the spring, large group discussions occurred about group work problems that arose so students could share their ideas and reasoning for solving problems they and their classmates faced. Group discussions were not scheduled, but rather happened as the need arose. These discussions helped students learn ways to take responsibility for solving their own problems.

**Intellectual environment of science classroom.** The intellectual environment honors what is important to the students. This environment does not narrowly focus on
curriculum determined to be important for the student, but rather uses student interest where students pursue learning where they are curious by asking questions, exploring ideas, and directing their own learning (Katz, 2015). The intellectual environment helps students find meaningful connections to the content standards.

In science class, students spent time on investigations that interested them, but also helped meet required state science expectations for fifth grade. Students also had time to work on solving problems they determined were important to solve in ongoing invention and innovation projects. The invention and innovation projects could not guarantee that each student would meet specific fifth grade science standards, but were determined by the teacher to be valuable learning experiences, so she entwined opportunities for working on inventions and innovations throughout the year during science class. Students could also choose to work on their projects during study hall or any free time. As students worked on their projects, they shared what they were working on with other students seeking feedback to help refine their thinking and improve their work. As the year went on, these purposefully scheduled sharing times began to occur more spontaneously as the class developed into a community of learners.

The invention and innovation design process as a context for examining creativity. A fifth grade project that provided a rich context for examining student creativity for this study was an invention and innovation design process project. This was inspired by the 2015 STEM Innovator Canvas (Flynn & Bowlus, 2015) designed for high school and college students (See Appendix D) which was adapted from the work of Alex Osterwalder, Business Model Generation (Osterwalder & Pigneur, 2010) (See Appendix
E). In the researcher’s adaptation for fifth graders, she first introduced the process step-by-step in an almost teacher-directed fashion to help her students work through it. As students worked through their first project, they began to understand the process and how you move back and forth as appropriate for your work. Students began to get excited about the possibilities and started to find problems they wanted to solve. They learned some problems are more important to spend resources on and that some are possible to solve while others are not so simple. The students’ journey was not simple, straightforward, or perfect. However, that was the power of the process. They learned to look to each other for feedback on improving their projects and became more self-directed in their creative endeavors. A diagram of this process can be seen in Figure 1.

Figure 1 Invention and Innovation Design Process
(A larger version of this Figure can be found in Appendix B).
Participants

In Csikszentmihalyi’s (1996) quest to determine what creative people are like, how the creative process works, and what conditions encourage or hinder the generation of original ideas, he selected creative people to interview and analyze. He selected creative people for his study based on three main conditions: 1) the person had to have made a difference to a major domain of culture; 2) he or she had to be still actively involved in that domain; and 3) he or she had to be at least 60 years old. In this study, the researcher’s quest was to determine fifth grade students’ perception of creativity, what they value about their experiences in a student-centered, inquiry-based science classroom within a STEM Framework that called for creativity, and the students’ perception of what supported their creative experiences. She selected creative students for her study based on their creative behaviors within the project involving invention and innovation.

To ensure the researcher’s definition of creativity for selection of creative students aligned with research, a table was created to compare the researcher’s criteria for identifying creative students as defined by seminal researchers on creative people (Csikszentmihalyi, 1996; Torrance, 1970) and a synthesis of research working to define creativity and how it might be measured (Said-Metwaly et al., 2017). Definitions suggested by Csikszentmihalyi and Torrance were selected because of these researchers’ status in research on creativity. Also included was the synthesis of creativity research by Said-Metwaly et al. (2017) because the researchers emphasized the diversity in definitions of creativity. Table 3 illustrates the alignment between the literature and the researcher’s definition of creativity.
Table 3 Alignment between the Literature and Researcher’s Definitions of Creativity

<table>
<thead>
<tr>
<th>Creativity as Defined by the Literature (Csikszentmihalyi, 1996; Said-Metwaly et al., 2017; Torrance, 1970)</th>
<th>Creativity of 5th graders as Perceived by Researcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Problem finding: Designing way to solve problem, then doing it</td>
<td>1. Comes up with interesting ideas; Open to new ideas; Finds problems to solve; Tries different ways to solve problems; doing, making, testing</td>
</tr>
<tr>
<td>2. Not following a rote, linear process</td>
<td>2. Thinks harder</td>
</tr>
<tr>
<td>3. Not looking for easy answers</td>
<td>3. Perseveres through frustration</td>
</tr>
<tr>
<td>4. Produces something new that is valuable and accepted</td>
<td>4. Develops interesting products</td>
</tr>
<tr>
<td>5. Always curious and asking questions</td>
<td>5. Always thinking of new ideas; insightful; communicates thinking with others</td>
</tr>
<tr>
<td>6. Accepting of ambiguity in order to think outside box</td>
<td>6. Thinks outside box; original</td>
</tr>
<tr>
<td>7. Willing to take risks / Attracted to challenges</td>
<td>7. Willing to take risks; persistent; resilient</td>
</tr>
<tr>
<td>8. Willing to spend the time needed / Complete absorption in work / Focused</td>
<td>8. Passionate about work; Shows pride in work; Sustained work on project; Shows enthusiasm when working</td>
</tr>
</tbody>
</table>
Informed consent was sought for this study. Parents and students were informed that this study would examine students’ perceptions of their experiences in a student-centered, inquiry-based science classroom and how their experiences influence their work. The study would include student interviews, artifacts, and observations. Participation was totally voluntary. Parents were informed they had a choice whether or not they were willing to allow data from observations, photographs of their child working, artifacts from their child’s work, and their child’s interviews to be used in this study. Parents and students were also informed that they could withdraw at any time.

Nine participants were selected by the researcher based on their creative behaviors within the innovation and design project. Pseudonyms were assigned. Four of the students were male and five were female. Seven of the participants were Caucasian, one was black, and one was biracial. Creativity observed within each student can be seen in Table 4.
<table>
<thead>
<tr>
<th>Traits of Creativity</th>
<th>Name</th>
<th>Creativity Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Comes up with interesting ideas; Open to new ideas; Finds problems to solve; Tries different ways to solve problems; doing, making, testing</td>
<td>Felicia</td>
<td>1, 2, 3, 4, 5, 8, 9</td>
</tr>
<tr>
<td>2. Thinks harder</td>
<td>Nolan</td>
<td>1, 2, 3, 4, 5, 8, 9</td>
</tr>
<tr>
<td>3. Perseveres through frustration</td>
<td>Georgia</td>
<td>1, 2, 8</td>
</tr>
<tr>
<td>4. Develops interesting products</td>
<td>Axel</td>
<td>1, 2, 8</td>
</tr>
<tr>
<td>5. Always thinking of new ideas; insightful; communicates thinking with others</td>
<td>Jake</td>
<td>1, 2, 3, 4, 5, 7, 8</td>
</tr>
<tr>
<td>6. Thinks outside box; original</td>
<td>Emerson</td>
<td>5, 8</td>
</tr>
<tr>
<td>7. Willing to take risks; persistent; resilient</td>
<td>Bella</td>
<td>1, 2, 4, 8</td>
</tr>
<tr>
<td>8. Passionate about work; Shows pride in work; Sustained work on project; Shows enthusiasm when working</td>
<td>Danica</td>
<td>1, 2, 3, 4, 5, 8, 9</td>
</tr>
<tr>
<td>9. Uses own initiative</td>
<td>Harmony</td>
<td>1, 2, 5, 8</td>
</tr>
</tbody>
</table>

**Data Sources and Collection Procedures**

This study’s purpose was to capture the essence of students’ lived experience of creativity in a student-centered, inquiry-based science classroom within a STEM Framework through the collection of 1) student interviews, 2) observational records of students’ actions collected by the teacher, and 3) student artifacts.

**Teacher Observational Records**

Teachers often use observational records to document what a student says or does that provides the teacher insight into how the student is thinking or processing information. In this study, researcher observational records were used to help capture very specific moments of student lived experiences to help answer the research questions.
Protocol for collecting observational records. Observational records were taken when students were working in small groups. To collect these observations, the researcher would stand to the side of a group with a clipboard, paper, and pen, and observe the students’ actions and conversation, taking note of where and who they were working with, and what they were doing and discussing. She would then move on to collect an observational record from another small group.

Student Interviews

Qualitative research informed by phenomenological perspectives collects data from informal, interactive interviews that capture the actual essence of experiences (Moustakas, 1994). The researcher creates an interview environment that allows the person being interviewed to feel comfortable to comprehensively share their experiences. In this study, open-ended, loosely structured student interviews were conducted by the researcher in order to learn about her students’ lived experiences in depth (Polkinghorne, 1989).

Protocol for student interviews. Student interview questions were generated by adapting Csikszentmihalyi’s Interview Protocol (Csikszentmihalyi, 1996, p. 393-397). Csikszentmihalyi famously interviewed 91 exceptional individuals to illustrate “what creative people are like, how the creative process works, and what conditions encourage or hinder the generation of original ideas” (Csikszentmihalyi, 1996, p. 12). One of Csikszentmihalyi’s (1996) purposes for doing his research on creative people was “to learn, from the lives of such men and women, how everyone’s life could be more creative” (p. 343). This study’s purpose was to learn what experiences students value as
well as what supports their experiences, thus an adaptation of Csikszentmihalyi’s Interview Protocol (See Appendix A) should help elicit these ideas. Questions were adapted to make them more accessible to students. The order of the questions was changed slightly in a way that made sense for flow of thinking during the interview process (See Appendix B). The researcher used the same questions for each interview but was flexible in following information students shared that deepened understanding of student answers. Interviews were recorded for review. Interviews took place in an empty classroom during non-academic times such as recess and study hall. A second round of interviews of participants was conducted to probe for further information from students about their perceptions and experiences with creativity. The researcher determined this additional round of interviews was necessary after listening to the recordings of the initial interviews and realizing not enough data was collected about creativity.

Student Artifacts: Student Writing and Photos

Photos provide a way to remember details about students experiences (Merriam & Tisdell, 2016), and thus were used as tools to tap into students’ lived experiences. In essence, student artifacts helped capture actual student lived experiences as accurately and effectively as possible to answer the research questions as well as to supplement the experiences described by students in interviews.

Protocol for collection of student artifacts. Samples of student writing were collected and photos were taken of students working and student-created artifacts. In mid-April, the researcher tasked the students with writing down their ideas about “What is Creativity?” She assured students there were no right or wrong answers but she wanted
to know what they thought. She collected the writing as data for the research study. At the beginning of May, she had students write about what they thought the purpose for school was. Again, she assured students she wanted to know what they thought and collected the papers to use for the study.

**Data Collection and Preparation for Analysis**

Data was collected in the form of interviews, observations of students at work, and student artifacts. Student interviews were conducted at the end of March with a follow-up at the end of May. Classroom observations and photographic artifacts were collected during this same time span.

The purpose of data analysis is to follow a process that will answer the research questions (Merriam & Tisdell, 2016). “The researcher must glean from examples an accurate essential description of their contents and the particular structural relationship that coheres the elements into a unified experience” (Polkinghorne, 1989, p. 50-51). This study identified moments in the data that illuminated the actual essences of lived experiences that helped answer the research questions as accurately and effectively as possible (Moustakas, 1994).

Using the constant comparative method, the researcher went back and forth looking at the data and comparing it to emerging ideas. The researcher started by listening to the recorded interviews to get a sense of the experiences the students were describing. Then all interviews were transcribed. Next, the researcher immersed herself in the data, listening to the interview tapes as she followed along, reading the interview transcriptions again and again. The interviews were used to listen for students personally
identifying experiences that were meaningful to them and what factors supported those experiences. This was an iterative process to capture moments in the data of lived experiences (van Manen, 2016). The researcher went back and forth listening for the clearly defined pieces of meaning and writing them down while not yet looking at the meaning in the context of the research questions (Hycner, 1985). Next, the researcher used NVivo 12 Pro, a qualitative data analysis software package, to code the specific pieces of meaning students shared as they described their lived experiences, as she again read interview transcripts. This process helped the researcher begin to see the whole meaning in the experiences students shared and 51 codes were identified. The researcher then immersed herself in the data from observations going through a similar process as with the interviews. Codes from those specific pieces of meaning from the observations were then added into the same NVivo 12 Pro software program. Twelve new codes were identified, causing the researcher to realize many of the codes had similar features and enabling code reduction. Students’ writings and photos of them working and their work were also analyzed looking for specific pieces of meaning. These specific pieces of meaning were also coded into the same NVivo 12 Pro program. See Figure 2.
Figure 2 Example of NVivo 12 Pro
Next, the researcher spent time reviewing at the coded data and the raw interview, observational, and artifact data to refine and merge categories. The additional data helped strengthen what the researcher was finding in the whole meaning. See Figure 3.

Figure 3 Examples of Refining and Merging Categories

After the essence of the whole meaning was captured, the researcher examined the data for meaning that answered the research questions. Themes began emerging from the data. The emerging themes sparked interest in looking at the data in other ways as well. Next, the researcher looked for common themes in the meaning relevant to the research questions (Leedy & Ormrod, 2016). The researcher also included unique individual themes.
CHAPTER 4

ANALYSIS

Previous literature has suggested the importance of nurturing creativity in schools (Florida, 2004; Executive Office of the President, 2018; K. H. Kim, 2016; Csikszentmihalyi, 1999). The purpose of this qualitative research study was to examine creativity in schools through the lens of fifth grade students in a student-centered, inquiry-based science classroom within a STEM Framework. The impetus for this dissertation developed from the researcher’s belief in the importance of providing learning environments that nurture students’ creativity. This study examined creativity to answer three questions:

Research Question 1: How do students perceive creativity in a student-centered, inquiry-based science classroom within a STEM Framework?

Research Question 2: What do students value about the experiences within a STEM Framework in a student-centered, inquiry-based science classroom?

Research Question 3: What factors supported their experiences?

Data was analyzed using the constant comparative methodology informed by the work of Glaser and Strauss (1967). The researcher immersed herself in the data, listening to interview tapes as well as reading interview transcripts and observation data repeatedly in an iterative process (Merriam & Tisdell, 2016) to capture actual lived experiences (van Manen, 2016) students personally identified that were meaningful to them and what factors they perceived that supported their experiences. In how fifth graders perceive creativity, two themes developed: 1) actions of being creative, and 2) characteristics of a
creative person. Data around what experiences students value emerged in three themes: 1) valuing authentic learning, 2) valuing collaborative work, and 3) valuing a grade on a paper. Three elements of support emerged: 1) relevance, 2) relationships, and 3) feedback.

Fifth Grade Students’ Perception of Creativity

Previous studies reported difficulty in defining creativity (Said-Metwaly et al., 2017; Lau et al., 2004). Like these studies, the fifth grade students’ perceptions of creativity were diverse. Two of the students expressed perceptions of creativity in the context of artistic artifacts (Emerson, May 21 Interview; Harmony, May 21 Interview). One student described creativity as a human talent and not something one can purchase from a store (Georgia, May 21 Interview). Another student emphasized the impact of creativity, and that it “could be for good or bad,” (Jake, Creativity Writing) reflecting class discussions around creative innovation having either a positive or negative impact on the social or natural environment.

Despite differences in student perceptions of creativity, analysis of student data also found similarities in students’ perceptions. Students described creative people as adventurous and able to think outside the box. Nolan (May 21 Interview) stated creative people enjoy “finding new ways” to do things. Bella agreed, sharing how creative people are “thinking of things that, like, aren’t already a thing” (Bella, May 21 Interview). Student perceptions of creative people aligned with research indicating creative people enjoy challenges (Torrance, 1970) and are flexible in considering alternate possibilities (Csikszentmihalyi, 1996).
Immersing herself in the data reading interview transcripts and student writings repeatedly, the researcher noticed students’ perceptions of creativity suggested ideas within two themes: 1) the actions that are evidence of being creative, and 2) character traits of people who are creative, as shown in Table 5. Further description follows.

Table 5 Students’ Perceptions of Creativity

<table>
<thead>
<tr>
<th>Actions of Being Creative</th>
<th>Characteristics of a Creative Person</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Using your imagination</td>
<td>• Original</td>
</tr>
<tr>
<td>• Using your own ideas</td>
<td>• Adventurous</td>
</tr>
<tr>
<td>• Your best thoughts come out</td>
<td>• Thinks outside the box</td>
</tr>
<tr>
<td>• Doing your own thing</td>
<td>• Artistic</td>
</tr>
<tr>
<td>• Doing, making, testing, inventing</td>
<td>• “Into” work</td>
</tr>
<tr>
<td>• Trying things in different ways</td>
<td>• Enthusiastic and happy with work</td>
</tr>
<tr>
<td>• Trying to figure things out</td>
<td>• Responsible</td>
</tr>
<tr>
<td>• Thinking harder</td>
<td>• Can be creative in different ways</td>
</tr>
<tr>
<td>• Collaborating with others for feedback and for more ideas</td>
<td>• Everyone is creative in some way</td>
</tr>
</tbody>
</table>

Acts of Being Creative

The students perceived using one’s own ideas and “doing your own thing” as creative. Jake explained that when being creative, “you make something up in a different way” (Jake, Creativity Writing). Felicia agreed, sharing, “You don’t copy anyone and it’s just something that is all what you thought and made with your own ideas” (Felicia, Creativity Writing). Danica further emphasized originality when she wrote, “Creativity is made of your mind. If you think of something and create it or bring it to life, you used
your creativity to make something” (Danica, Creativity Writing). Danica’s focus on originality was also revealed in her interview:

I think it makes it creative because I thought of it myself, not like in art when like your teacher tells you what to do, and then you have to try to make it yourself. It’s creative because, like, I thought of it all by myself. (Danica, May 21, 2019 Interview, 4:36-4:45)

Student perceptions of creative actions align with research suggesting creativity starts with something new and original (K. H. Kim, 2016; Csikszentmihalyi, 1996; Sternberg, 1999; Runco, 2014). Students felt that creative people tried to do things in unique ways. For example, Felicia wrote “I think creativity means something that you make yourself and think of it yourself” (Felicia, Creativity Writing).

**Characteristics of a Creative Person**

Students described creative people as “fun and adventurous” (Emerson, Creativity Writing), and willing to take risks to be creative and persevere. For example, Bella wrote:

Creative people do things that aren’t normal like if you add a bucket to a clock, they are creative for doing something that you wouldn’t normally do. I mean a bucket and a clock is two things you don’t normally put together. So they are being creative by thinking outside the box. (Creativity Writing)

Nolan (May 21 Interview) stated creative people get “really into it”, or what Csikszentmihalyi (1996) described as “flow”.

Student perceptions of creative people align with research informing us creative people enjoy challenges (Torrance, 1970) and are flexible in considering alternate possibilities (Csikszentmihalyi, 1996).
Upon the creation of the table illustrating student perceptions of creativity, the researcher became curious how closely the students’ perceptions aligned with research and her own perception. She found intersection among all three as can be seen in Table 6.

Table 6 Intersection of Creativity among Research, Researcher and Students

<table>
<thead>
<tr>
<th>Creativity as Defined by Research (Csikszentmihalyi, 1996; Said-Metwaly et al., 2017; Torrance, 1970)</th>
<th>Creativity of 5th graders as Perceived by Researcher</th>
<th>Fifth graders’ perception of Creativity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Problem finding: Designing way to solve problem, then doing it</td>
<td>1. Comes up with interesting ideas; Open to new ideas; Finds problems to solve; Tries different ways to solve problems; doing, making, testing</td>
<td>1. using your imagination; using your own ideas; responsible</td>
</tr>
<tr>
<td>2. Not following a rote, linear process</td>
<td>2. Thinks harder in a way that demands thinking be flexible</td>
<td>2. Thinking harder</td>
</tr>
<tr>
<td>3. Not looking for easy answers</td>
<td>3. Perseveres through frustration</td>
<td>3. Trying to figure things out; into work</td>
</tr>
<tr>
<td>4. Produces something new that is valuable and accepted</td>
<td>4. Develops interesting products</td>
<td>4. Doing, making, testing, inventing; original; artistic</td>
</tr>
<tr>
<td>5. Always curious and asking questions</td>
<td>5. Always thinking of new ideas; insightful; communicates thinking with others</td>
<td>5. Collaborating with others for feedback and for more ideas; enthusiastic and happy with work</td>
</tr>
<tr>
<td>6. Accepting of ambiguity in order to think outside box</td>
<td>6. Thinks outside box; original</td>
<td>6. Trying things in different ways; can be creative in different ways, thinks outside the box</td>
</tr>
<tr>
<td>7. Willing to take risks / Attracted to challenges</td>
<td>7. Willing to take risks; persistent; resilient</td>
<td>7. Adventurous</td>
</tr>
<tr>
<td>8. Willing to spend the time needed / Complete absorption in work / Focused</td>
<td>8. Passionate about work; Shows pride in work; Sustained work on project; Shows enthusiasm when working</td>
<td></td>
</tr>
</tbody>
</table>
What Students Value about their Experiences

The second research question asked, “What do students value about the experiences within a STEM Framework in a student-centered, inquiry-based science classroom?” Data was collected from interviews, observations, and artifacts and coded into an NVivo 12 Pro software program. Emerging themes from the data analysis indicated all of the students found authentic learning and collaboration valuable. One student stated a good grade on a paper was valuable.

The Value of Authentic Learning

Authentic learning involves students engaging in investigating and trying to solve real-world, multifaceted problems that they find important (Lombardi, 2007). The present study found creative students valued authentic learning as a context for creativity. Authentic learning experiences students enjoyed were experiences designed to challenge students to think, independently figure things out, and persevere. Specific examples mentioned by students were active learning within the experiences of 1) an invention and innovation project, 2) engineering a good tasting pancake, and 3) creating a circuit to light a light bulb. Rich descriptions emerged as students explained these authentic learning experiences: doing, making, inventing, and testing stood out to them and were valued because students perceived the experiences to be relevant and worthwhile, not just following steps on a worksheet. They expressed these experiences made them think harder.

Invention and innovation. Students followed a non-linear, flexible design process as they developed interesting inventions and innovations to solve problems important to
them. They wrote information and drew diagrams in their design notebooks to keep track of their thinking as they worked through the process. Students began by choosing a problem they thought was important to spend time and resources solving. They considered the value of solving the problem and interviewed peers and others to find out whether they also thought the problem was worth solving. If the problem was also considered valuable to solve by others, they proceeded with their work. If not, they pivoted and returned to finding a new problem to solve. After finding a valuable problem to work on solving, students generated different ideas for solving the problem. They again interviewed peers and others to refine their ideas for solutions. Then students worked to develop a prototype to help illustrate their idea for their invention or innovation. Students moved back and forth through the different parts of the design process as they developed their invention or innovation. Students also worked on presenting their projects as they explained their thinking through the whole endeavor.

Throughout these experiences, they learned to consider and use feedback.

In her interview, Felicia described how working through the invention and innovation process made her think more:

Yeah, because if you don't really, like, think about it then you're not learning anything. It's kind of like a waste of your time. So, like, if you want to have a good invention/innovation and actually, like, have something valuable, then you actually need to think 'cause that’s basically what, like, science class is about. (March 29, 2019 Interview, 8:22-8:41)

Axel described how he valued working on his innovation because it felt good to solve a problem for other people:
I would probably be most proud of... yeah I would probably stick with the innovation and research thing because...Like, what I invented and what I could, like, how I accomplished it....Like, mine was, like, a pencil holder that you just stick onto the side of chairs so you don't lose your pencils and stuff. So I was really proud of, like, I had to figure out a way, like, to make sure you don't lose your pencils.... It makes me feel really good because lately people have been losing their pencils, like, every now and then. And there's normally... you have to borrow from a teacher and they never get it back. (April 2, 2019 Interview, 1:41-2:48)

Jake’s interview revealed the invention and innovation experience enabled him to follow his own ideas rather than following a procedure from a worksheet. “I also like doing that [invention and innovation] because I guess it's also on your own and you kinda get to make up your own ideas and it's not working off a sheet of paper” (April 3, 2019 Interview, 2:19-2:29).

**Engineering a good tasting pancake.** In fifth grade, making pancakes was not a straightforward, follow-the-recipe activity. Students did not have a recipe to follow; rather, they spent time testing different ratios of ingredients to find one ideal for a good tasting pancake. Then students also spent time figuring out the best way to know when to flip a pancake. They spent days exploring this while they also keep data of their investigations in their science notebooks. There was time for student scientific discourse throughout this process.

Jake described how he valued doing things for himself when asked which authentic learning experience he most enjoyed, stating, “Probably making the pancakes and getting to, like, do it on our own and not having somebody else do it for us” (April 3, 2019 Interview, 0:35-0:43).
Bella’s interview also referenced the pancake experiences and described her satisfaction in being able to test things to see how that affected results, trying to figure out how to do things, and the desire to persist in her efforts.

It was fun making pancakes and stuff because you could test them and add different amounts of ingredients to see if it would be good or bad. And the light bulb one was fun trying to figure out how to do it. Like, you might not always be right the whole time, but sometimes like you just had to figure it out. And you keep wanting, you want to make it light. (April 4, 2019 Interview, 0:59-1:17)

Creating circuits to light a light bulb. Students were given access to wires, batteries, and bulbs, but no directions on how to create a complete circuit to illuminate a light bulb. There was not one right way to complete the circuit. Most had no experience working with electricity, and they worked through frustrations trying to get their bulb to light. Felicia shared the importance of learning by doing within this authentic experience.

She reported how she had to think more and actually figure out how to make something work rather than guess and fill in an answer on a worksheet:

In science we were doing like the light bulb thing, we had to try to get a light bulb to light up. And there’s a few different ways you could do it. I was feeling really creative, like, trying to get the different ways to make it light up, like, using different techniques and stuff…..we were using, like, different strategies to make the light bulb go off and like attaching different wires to it and like instead of just doing it one way, like doing it only that way. We tried different things to try to make it light up instead of just one……it was really fun, and it helped me learn about that, like, more because I didn’t really know how light bulbs lighted up, I just really didn’t think that much about it…it helped me because, um, it made me, like, think more about it and like yeah, I just thought about it more……because it’s not just like any other assignment, it’s not just like you fill in like an answer bubble, like you actually have to like attach it and like, make it work. Like it’s just not like you can guess on it, like you have to make it work and like figure out ways to make it work. (Felicia, May 21, 2019 Interview, 3:11-4:58)
Valuing Collaborative Work

A second theme that emerged from the data was valuing collaborative work. The findings of this study indicate fifth grade students are willing to negotiate within a collaborative group to capitalize on the diverse ideas within a group. Students explained they learned to interact better with others and get along with diverse people. Danica described how working in groups helped her learn how to interact with others and that she wouldn’t always get her way:

[You] learn, and like, be able to interact with other kids. not just be by yourself...you don’t always get your way in life and if you’re just by yourself, you always get to do what you want, but if you’re with other kids, you might have to do what they want sometimes. (May 21, 2019 Interview, 2:57-3:21)

Felicia described how working in groups helped her learn to work better with different people. “It helped me better in group work and stuff so I'm better at working like, with groups, or like different people” (April 8, 2019 Interview, 2:09-2:16).

Students described how collaboration allowed students to learn to work better with others as well as eliciting more ideas. Bella shared how working with others produced more ideas and was like working with a team: “I like working with others because they can help you, like say they have really good ideas….And you can work together as a team” (April 4 Interview). Georgia shared similar experiences: “I like working with others more because others, other people, have ideas that I wouldn’t have even remotely thought of” (March 29 Interview). Like the leadership in IDEO (Kelley et al., 2013), fifth grade students valued collaboration as different people bring different strengths and ideas to the group.
Factors that Supported Students’ Experiences

The third question of this study asked, “What factors support the students’ experiences?” In the coding of data that referenced what students deemed important in their science class, three themes emerged: 1) Relevance, 2) Relationships, and 3) Feedback.

Relevance

The students’ sense of importance of the work they were challenged to complete suggested the significance of relevant work and the role that choice played in making work relevant. Students specifically mentioned the importance of choosing what to work on, who they worked with, and where they worked.

Choice in what to work on. Data suggested a positive attitude and increased student effort occurs when students are given a sense of choice in their learning.

Harmony stated:

Like, let’s say I’m at home, and my parent says, “You need to do the dishes because I want you to.” If you decide to do the dishes then you’d be more happy about it because you chose it by yourself, so then you wouldn’t pout about it...when it’s your decision you kind of have more character doing it because you know you want to do it. And if she tells you to do it... you wouldn’t want to do it at the time. (April 1, 2019 Interview, 22:54-23:40)

Georgia described the importance of being able to choose what problem she was working to solve in the invention and innovation design process: “If it was somebody else’s problem then we wouldn’t feel as much that we needed to fix it” (March 29, Interview, 3:02-3:10). Felicia agreed, stating, “I would enjoy my work more, if I got to choose” (April 8, 2019 Interview, 10:20-10:23).
Students described how choice in what to work on makes projects relevant and enjoyable for them. Jake described how learning needs to be fun so students are interested in learning. “If you are learning and it is not fun, then you’re not really interested, but if it’s something fun, then I would be a lot more interested. If you’re interested, you can learn more and ask questions” (May 21, 2019 Interview, 2:32-2:46). Additionally, Jake described the connection between fun and learning. “I would rather go to school to have fun learning than go and get taught something boring” (Purpose of School Writing).

Students shared how they persevered when they worked on solving problems they chose to solve. Axel described sticking with solving the problem he chose for invention/innovation:

Probably the thing that made me stick with it was that I was already so far ahead in the, like, situation, like the problem. I didn't want to just stop it there and then go work on something else. I wanted to just to keep going and see if I could fix it. (April 2, 2019 Interview, 3:33-3:50)

Students having choice in what to work on resulted in them working on their own projects at their own speed. Students’ work was not linear nor at a designated pace, and they recognized the uniqueness of having this choice and even pondered how others may get the wrong impression of this active classroom. Georgia described what an outsider might see when entering the science classroom:

They might think it’s a little bit crazy in there, because there’s people interviewing, and people taping and working and talking, and it’s a little bit loud, but not too loud. There’s, it’s just voices. And like, so if they walked in, they’d probably think, whoa, this is crazy. But, like, it’s actually not. You’re kind of just working on your own thing, or with your partner, just like that...Some people are interviewing people, some people are working on their project. Some people are
going out to get cardboard, some people are, or tape, or whatever, or, or hot gluing. There's a lot of stuff happening. (April 1, 2019 Interview, 9:30-19:04)

The lived experiences revealed by the students align with the published literature. Like creative adults, the fifth graders thrived when their own creative work and problem solving was relevant and honored by the gift of time to spend problem solving (K. H. Kim, 2011; de Souza Fleith, 2000; Jeffrey & Craft, 2004; Torrance, 1970). Students highly valued the autonomy, self-direction, and opportunity to engage in meaningful work, which increases engagement (Daniels & Arapostathis, 2005).

**Choice in collaborative work.** Being able to choose with whom to collaborate also made work relevant. Bella communicated that being able to choose when and with whom to work was important to her: “It depends on what the project is. Like I like getting to choose…some people work better alone, some people work better together. So, if you get to choose working together or alone, you get to decide” (April 4, 2019 Interview, 13:29-14:02).

Felicia agreed:

> Uh, yeah because some of my friends if they ask me like, "Hey, do you want to be my partner for the invention innovation?" Like, I don't feel like I have to say yes. Like, if I want to work alone then I'll be like, "Oh sorry, I kind of want to work alone on this." But if they're like, if I want to work in a group, I'll be like, "Yeah, like, I'll work in the group with you." Like, you can kind of choose which one you wanna do. (March 29, 2019 Interview, 14:27-14:47)

**Choice in where to work.** Additionally, data suggested students enjoyed flexible space for working. Interview and observational data suggested that students chose the working space that fit their needs at that time. Students described how important it was to...
choose their work area to get the space they needed, be near necessary tools and resources, and be in close proximity to students they needed to complete the work.

Georgia explained, “It's important to have, like, what you need and the workspace, because if you don't have the workspace, then you might not be able to get as much done” (April 1, 2019 Interview, 5:49-5:58). Axel agreed by adding:

Um, probably what I liked about how much space you get in here is like... I like it because like sometimes you get, like, a whole table to work at or you share one with someone, or you work on the ground or the counter, and like the amount of space that you can get is enough for me just to work. (April 2, 2019 Interview, 22:07-22:27)

The expressions of the fifth graders support the ideas of Fredericks et al. (2004), who suggested learning environments that support autonomy, choice, and authenticity enhance the growth of creative problem solvers.

Choice and one student’s conflicting data. In opposition from the rest of the study participants treasuring choice, in his interview, Nolan described how he wanted the teacher to make choices for him. When explicitly questioned about whether he wanted choices about who he worked with, what he worked on, and where he worked, Nolan expressed how he wanted to work alone and wanted the teacher to tell him what to work on and where to sit. He voiced how this would help him stay focused and know what to do. He explained that students are supposed to be quiet, listen to the teacher, and do what they are told. However, in other parts of his interview, specific pieces of meaning from the lived experiences he described suggested something different and observations and photos of him working supported this difference. The rest of the data analysis from Nolan’s lived experiences suggested he consistently chose to work with others, made his
own choices about the project he was working on, and chose where to work. The researcher began to wonder what the story was behind the contrast in Nolan’s expressing that he wanted the teacher to direct his learning and the data that suggested he actually valued choices about his work. What was the story behind him saying what he said? The researcher began considering Nolan’s challenging background, wondering if it was possible other people’s perspectives were behind what he expressed he wanted as opposed to what he actually chose to do.

**Relationships**

Positive, caring relationships emerged as a theme as students shared experiences they valued in science class. Such relationships were built in collaborative work with peers, positive relationships with visiting adults, and with their teacher. Relationships would be a necessary support structure for many pieces students shared as important and of value in science class: collaboration, safe environment for sharing work, adult time, perspective and respect, and teacher role in learning.

**Relationships built through collaboration.** Collaboration emerged as an important part of relationships. Interview data suggested the majority of students like to work with groups. Students suggested working with other people elicited more ideas and support, while working alone offered autonomy.

Observational data and photos of students working showed eight of the nine participants consistently working with others. Students described how collaboration allowed them to learn to work better with others as well as eliciting more ideas. One participant expressed his preference to work alone. However, photographic artifacts
captured him consistently working with others, signaling he could also work with others.

Interview data also suggested that three students sometimes liked to work alone and sometimes liked to work with others.

Georgia described how you get more ideas when you collaborate with others:

I like working with others more because others, other people, have ideas that I wouldn’t have even remotely thought of. So like, if they have ideas, and then I’m gonna get more ideas and make it better than if I was on my own, thinking by myself, not having...Two heads are better than one. (March 29, 2019 Interview, 18:11-18:33)

Bella described working with others as teamwork, and discussed producing more ideas through collaboration:

I like working with others because they can help you, like say they have really good ideas. And then you have no ideas when you’re by yourself. And they can, like, help you have like ideas with them. And you can work together as a team. And you can get more work done. (April 4, 2019 Interview, 12:21-12:35)

Felicia described how working with others allowed you to share ideas and improve your work:

Like, you're able to connect people and, like, share ideas and stuff to make things better instead of, like, going with, um, only the- the idea that you like and, like, when you work with a group you get better ideas and, like, better feedback and stuff. (March 29, 2019 Interview, 1:30-1:48)

Relationships built within a safe learning environment. Leadership at IDEO and Google recognize positive work cultures as necessary for innovation, supporting an environment where people listen to each other, share ideas, and work together and not against each other (Kelley et al., 2013; J. Kim, 2013). This study found the fifth graders’ creativity thrived in this same type of environment in their educational setting. This was
contingent upon responses of adults within this learning environment, namely the members of the STEM panel and their teacher.

Students had opportunities to present their inventions and innovations to a STEM panel consisting of adults two times a year. The panel membership consisted of four to six invited adults from the community and nearby university and changed depending on the availability of panel members. Community member panelists included an engineer, business owners, and a lawyer. Members from a nearby university included professors and university students from technology education. Fifth grade students presented their inventions and innovations, explaining the processes they went through as they developed their projects. The panelists listened, asked questions, and gave students feedback. The audience also had the opportunity to ask questions and give feedback. Georgia shared how she felt her work was respected and taken seriously by the panelists. She described how some students were nervous about presenting to the STEM panel because they were worried about their work being judged as unimportant and frivolous. This discomfort was alleviated once the students began presenting their ideas:

Most people think that they’re [the panelists] judging you, but they’re not. So like, after you get over that fear, then you kind of just act like you’re having a normal conversation with them, and then like, it kind of just takes the fear away, and then it’s fun. (April 1, 2019 Interview, 3:13-3:29)

The students’ relationship with their teacher also emerged as significant in setting the stage for a positive classroom work environment. Data suggested participants believed the role of their teacher was not to be giving answers, but rather to allow students to figure things out themselves. Felicia explained that her teacher challenged her, made her think, and made her smart. “You [the teacher] wouldn’t just tell us the answer
and, like, you made us solve it on our own and, like, actually made us think. And you like, challenged us and that actually made us smart and stuff” (March 29, 2019 Interview, 9:03-9:019). Harmony shared how important it was that her teacher not help too much so the student retained ownership of the work. “I think it is good she [the teacher] helps us a little bit, ‘cause if she helped us way more than we needed to, she would be the one doing the invention, doing the idea” (April 1, 2019 Interview, 14:14-14:28).

Jake appreciated the autonomy his teacher allowed. “Usually teachers, like, will do something for you and then maybe give it to you so you can look at it or something and that’s not bad, but I’d rather do it on your own” (April 3, 2019 Interview, 0:50-1:02). The positive relationships with adults were deepened by how they responded with their feedback, the third theme that emerged.

Feedback

Emerging from the data was how students valued the time and attention adults gave to them in providing honest feedback. Georgia shared her experiences presenting to the STEM panel of adults and how they don’t judge you, but rather give you good feedback. “They [the STEM panel] don’t judge. They kind of listen to you, and then they give you good feedback” (March 29, 2019 Interview, 8:37-8:41). Jake described how having adults actually listen to him made him feel happy.

[Presenting to panelists] was a valuable experience because they gave you honest feedback and it wasn’t just, like, somebody saying something…[Feedback] helps because people aren’t just saying stuff to just, like, get you away or something, they’re actually telling you….It made me feel happy because they actually listened. (April 3, 2019 Interview, 5:18-6:38)
Danica agreed on the importance of an adult’s honest feedback. “We got another person’s perspective...we wanted to get it from an adult...they [adults] would actually tell us what they really thought” (April 9 Interview, 10:27-10:54).

Students felt the adults’ honest feedback improved and enriched their work. Bella explained, “Feedback kind of helps you because once you get feedback, then that makes your idea better and better” (April 4, 2019 Interview, 6:39-6:45). Harmony shared how feedback helped improve her work: “We started changing our idea more and working on the feedback that they [the STEM panel] gave us to change it” (April 1, 2019 Interview, 9:13-9:17). Danica described how specific feedback made her think more and helped her improve her idea for a unique alarm clock:

We got some pretty good feedback. We had our punching one [an alarm clock that punched you in the nose when it went off] and they [the STEM panelists] told us that, like, someone could get hurt, and then they might sue us. And then we also had talked about the, a tickling one [an alarm clock that had an arm that reached out and tickled you when it went off], but they said that, like, “What if they just roll over to the other side of the bed and it doesn’t, like, touch you?” So then we had to think more. (April 9, 2019 Interview, 9:27-9:57)

Harmony reported how receiving feedback enriched her work:

I would describe feedback as fun because it’s like, more easy to work with if people give you feedback. ‘Cause if you just have your item and no one gives you feedback, you and your partner would be stuck and like, not know what to change with your, um, invention. (April 1 Interview, 12:05-12:22)

Summary

Fifth grade students’ perceptions of creativity involved how creative people are distinctive and do things in unique ways. This perception aligns with published
definitions of creativity as well as the researcher’s perceptions of creativity (Csikszentmihalyi, 1996; Said-Metwaly et al., 2017; Torrance, 1970).

Fifth grade students valued authentic learning and opportunities for collaborative work in their hands-on, inquiry-based science classroom within a STEM Framework that called for creativity. This aligns with what adults value in a work environment that calls for creativity (Kelley et al., 2013; J. Kim, 2013).

Fifth grade students valued the factors of relevance, relationships, and feedback in supporting their experiences in their student-centered, inquiry-based science classroom within a STEM Framework. This aligns with what research informs us nurtures creativity (Fredericks et al., 2004; Henriksen & Mishra, 2015; Jeffrey, 2006; K. H. Kim, 2011; Torrance, 1970).

A final note of interest is that similarities emerged from the data between what students valued most about science class and what they perceived as creative. The students’ perception of creative actions mirrored the actions they valued most about their science class. Students’ descriptions of the creative behaviors of “doing your own thing,” using your imagination and ideas, making, testing, inventing, and trying things out in different ways could be enacted in their science class when they were making, doing, inventing, testing, and innovating. Their perceptions of a creative person as being enthusiastic, creative, and “into” work were operationalized in their science classroom where they were enthusiastic and happy with work. See Table 7.
Table 7 Similarities between Students’ Perceptions of Creativity and What They Valued Most about Science Class

<table>
<thead>
<tr>
<th>Students’ Perceptions of Creativity</th>
<th>What Students Value Most about Science Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actions of Being Creative</td>
<td></td>
</tr>
<tr>
<td>• Doing your own thing</td>
<td>• Making, doing, inventing, testing, innovating</td>
</tr>
<tr>
<td>• Using your imagination</td>
<td>• Thinking harder</td>
</tr>
<tr>
<td>• Using your own ideas</td>
<td>• Working on things relevant to them.</td>
</tr>
<tr>
<td>• Your best thoughts come out</td>
<td>• Persevering to improve work</td>
</tr>
<tr>
<td>• Doing, making, testing, inventing</td>
<td>• Doing worthwhile work</td>
</tr>
<tr>
<td>• Try things in different ways</td>
<td>• Not following steps on a worksheet</td>
</tr>
<tr>
<td>• Try to figure things out</td>
<td></td>
</tr>
<tr>
<td>• Thinking harder</td>
<td></td>
</tr>
<tr>
<td>• Collaborating with others for feedback and for more ideas</td>
<td></td>
</tr>
<tr>
<td>Characteristics of a Creative Person</td>
<td></td>
</tr>
<tr>
<td>• Original</td>
<td>• Enthusiastic and happy with work</td>
</tr>
<tr>
<td>• Adventurous</td>
<td></td>
</tr>
<tr>
<td>• Thinks outside the box</td>
<td></td>
</tr>
<tr>
<td>• Artistic</td>
<td></td>
</tr>
<tr>
<td>• “Into” work</td>
<td></td>
</tr>
<tr>
<td>• Enthusiastic and happy with work</td>
<td></td>
</tr>
<tr>
<td>• Responsible</td>
<td></td>
</tr>
<tr>
<td>• Can be creative in different ways</td>
<td></td>
</tr>
<tr>
<td>• Everyone is creative in some way</td>
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</tbody>
</table>
CHAPTER 5

DISCUSSION

The purpose of this qualitative research study was to examine creativity in schools through the lens of fifth grade students in a student-centered, inquiry-based science classroom within a STEM Framework. The impetus for this dissertation developed from the researcher’s belief in the importance of providing learning environments that nurture students’ creativity. Previous literature has also suggested the importance of nurturing creativity in schools (Florida, 2004; Executive Office of the President, 2018; K. H. Kim, 2016; Csikszentmihalyi, 1999). This study examined creativity to answer three questions:

Research Question 1: How do students perceive creativity in a student-centered, inquiry-based science classroom within a STEM Framework?

Research Question 2: What do students value about the experiences within a STEM Framework in a student-centered, inquiry-based science classroom?

Research Question 3: What factors supported their experiences?

Implications

Society is demanding a more creative and innovative workforce, with employees who are able to look at problems differently, solve complex problems, and come up with new ideas. If schools are to prepare students to successfully contribute to society, they will need to consider how creativity and innovation can be nurtured within the classroom walls. The findings in this study inform individual teachers, school districts, and policymakers who are responsible for growing the next generation of creative innovators.
**Considering the Teacher’s Role in Nurturing Creativity**

The findings from this study assist classroom teachers in creating a learning environment that supports creativity and innovation. Listening to student voices compels these teachers to consider an educational environment that is sensitive to students’ interests and needs, open and flexible to take on their students’ creative ideas and problem solving, and responsive and supportive of students’ efforts. This study found students valued time to engage in authentic learning experiences that embraced active open-ended exploration of and experimentation with simple materials resulting in a creative and innovative end. Instead of didactic teacher-driven lessons focused on learning about STEM, the students in this study used every day materials such as wires, bulbs, and batteries to create unique working circuits. They took on the everyday experience of eating breakfast and turned it into engineering a recipe and process for producing a quality food product. Their exercise in creativity and innovation culminated in designing solutions to problems interesting and important to them. The open-ended nature of these experiences required the teacher to be flexible, supportive, and operating in a belief system that viewed all of the students as creative innovators with a desire to learn. This study showed that when a teacher created such an environment, students were motivated to pose their own problems, and persevere to figure out answers for themselves. Students in this study shared how this caused them to think harder and actually learn more when they had opportunities to test their ideas and figure out how to solve problems.
Teachers who wish to embrace the development of creativity and innovation can also learn from student voices on the importance of student choice. Instead of controlling student actions and behaviors through teacher-created rules, procedures, and activities, allowing student choice develops student agency and autonomy that leads to creativity and innovation. In the class of focus here, students had choice in what to work on (within parameters), with whom to work, and where to work within the classroom space. Students in this study expressed how they valued working with others. Working with peers helped them not only develop social skills, but enabled them to benefit from the diverse ideas that came from others.

Student voices inform teachers who want to nurture creativity and innovation in their classrooms that respectful relationships are important to their creativity. This study found that adults who take time to listen to, respect, and honestly respond to students’ ideas with specific and meaningful feedback are essential for creativity and innovation. The students in this study felt respected and valued when their teacher allowed them to take control of their own work and learning. They knew their teacher viewed them as capable of solving their own problems, allowing the work to be their own. Learning within this classroom was viewed as a process and students felt safe taking risks, knowing mistakes are okay and opportunities to learn. Such a classroom environment enables students to take on the vulnerability in asking for constructive criticism through feedback to improve their work.
Considering School’s Culture and Policy’s Roles in Nurturing Creativity

Nearly every public school district touts a vision for developing 21st Century Skills. The school district in this study is no different, stating on its website, “In addition to academic instruction, we will focus on 21st Century Skills and developing leadership within our student body.” The Partnership for 21st Century Skills (Trilling, Fadel, & Partnership for 21st Century Skills, 2009) calls for creativity and innovation as one of the essential skill sets of future citizens. However, the district in this study operates within a state that mandates frequent testing of narrow skills in literacy. The frequency of these tests dictates instructional time and instructional focus in order to lead children to conformity on grade level test scores. To navigate the state requirements of high-stakes testing, the teacher in this study has to regularly advocate for the creative and innovative learning environment she provides her students. Testing policies in literacy should be designed to benefit students, paving the way for a rich, full-bodied curriculum and educational environment that addresses the whole student instead of an educational environment engineered for performance in one domain.

According to the Executive Office of the President (2018), our nation needs an educational system that nurtures creativity and innovative problem solving in all students. The skills within STEM are universal as they help people make more informed personal decisions as well as prepare for the challenges of an ever-changing world. This study informs policymakers as they begin to consider what schools should really be doing to help support classrooms in nurturing creativity and innovation. It is essential that policymakers within literacy education coordinate with policymakers within STEM
education to collaboratively make decisions to nurture creativity in the classroom that increases performance in both domains.

**Limitations**

This study was a small, in-depth qualitative study of the lived experiences of the students in this one classroom. Thus the results are not generalizable. This study also does not tell us the story behind each of the students’ lived experiences. To gain more understanding of how to nurture creativity and innovation in schools, more studies involving a larger population will need to be conducted.

**Recommendations for Future Research**

This study examined the lived experiences of fifth grade students in their own science classroom environment designed to nurture creativity and innovation within the framework of STEM. The teacher’s report of advocating for this environment within a culture of mandated literacy standardized tests suggests future studies may want to examine the role of school-induced stress on students’ development of creativity and innovation, or whether environments that nurture creativity and innovation serve to alleviate stress in students. This study had nine participants that included four boys and five girls, a number too small to differentiate findings by gender. Future studies involving larger numbers of students may be able to discern whether there are gender differences in nurturing students’ creative and innovative work. Finally, this study found students valuing peers’ insights and contributions to their creative work, suggesting the development of positive peer relationships. A study examining the development of
empathy within environments that are designed to nurture creativity and innovation may shed light on the social development of the students who live in that environment.
REFERENCES


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Root-Bernstein, R. (2015). Arts and crafts as adjuncts to STEM education to foster creativity in gifted and talented students. Asia Pacific Education Review, 16(2), 203.


APPENDIX A:

Original Interview Protocol (Csikszentmihalyi, 1996)

<table>
<thead>
<tr>
<th>Part A: Career and Life Priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Of the things you have done in life, of what are you most proud?</td>
</tr>
<tr>
<td>a. To what do you attribute your success in this endeavor? Any personal qualities?</td>
</tr>
<tr>
<td>2. Of all the obstacles you have encountered in your life, which was the hardest to overcome?</td>
</tr>
<tr>
<td>a. How did you do it?</td>
</tr>
<tr>
<td>b. Any that you did not overcome?</td>
</tr>
<tr>
<td>3. Has there been a particular project or event that has significantly influenced the direction of your career? If so, could you talk a little bit about it?</td>
</tr>
<tr>
<td>a. How did it stimulate your interest?</td>
</tr>
<tr>
<td>b. How did it develop over time?</td>
</tr>
<tr>
<td>c. How important was this project/event to your creative accomplishments?</td>
</tr>
<tr>
<td>d. Do you still have interesting, stimulating experiences like this?</td>
</tr>
<tr>
<td>4. What advice would you give to a young person starting out in [subject’s area]?</td>
</tr>
<tr>
<td>a. Is that how you did it? If not how is your current perspective different from the way you started?</td>
</tr>
<tr>
<td>b. Would you advise [concerning importance of field]: Few social contacts or many? Mentors, peers, colleagues? Establish your own identity early or late? Work with leading organizations?</td>
</tr>
<tr>
<td>c. Would you advise [concerning importance of domain]: Specialize early or late? Focus on leading ideas or work on periphery?</td>
</tr>
<tr>
<td>d. Would you advise [concerning importance of person]: Intrinsic versus extrinsic reasons? Tie work to personal values or separate?</td>
</tr>
<tr>
<td>5. How would you advise a young person on why it is important to get involved in [subject’s area]:</td>
</tr>
<tr>
<td>a. Is that why it was important to you? If not, how is your current perspective different?</td>
</tr>
<tr>
<td>6. How did you initially become involved or interested in [subject’s area]? What has kept you involved for so long?</td>
</tr>
<tr>
<td>7. Have there been points when what you were doing became less intensely involving — seemed less interesting or important to you? Can you describe a time that stands out?</td>
</tr>
<tr>
<td>a. What were the circumstances?</td>
</tr>
<tr>
<td>b. What did you do?</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Part B: Relationships</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. If there has been a significant person (or persons) in your life who has influenced or stimulated your thinking and attitudes about your work…</td>
</tr>
<tr>
<td>a. When did you know them?</td>
</tr>
<tr>
<td>b. How did you become interested in them (e.g., did you actively pursue them)?</td>
</tr>
<tr>
<td>c. How did they influence your work and/or attitudes (e.g., motivation, personal or professional values)?</td>
</tr>
<tr>
<td>d. In what ways was he/she a good and/or bad teacher?</td>
</tr>
<tr>
<td>e. What kinds of things did you talk to this person about (e.g., personal, general career-related, specific problems)?</td>
</tr>
<tr>
<td>f. What did you learn from them? How to choose what problems to pursue? Field politics and marketing yourself?</td>
</tr>
<tr>
<td>2. Is it important for you to teach and work with young people?</td>
</tr>
<tr>
<td>a. Why?</td>
</tr>
<tr>
<td>b. What are you interested in trying to convey to them? Why?</td>
</tr>
<tr>
<td>c. How do you do this?</td>
</tr>
</tbody>
</table>
3. When you interact or work with a young student, can you assess whether they will be likely to leave the field or become successful in the field?
   a. Do you recognize people who are likely to be creative in their future work? How? What characteristics do they have?

4. Do you notice differences between men and women students/young people and male and female colleagues in the field? If so,
   In interests?
   In ability?
   Creativity?
   In the way they approach learning?
   In the way they interact with other people/colleagues?
   In how they define success and achievement?
   In their personal goals and values?
   In their professional goals and values?

5. What advice would you give a young person on how to balance their private life (i.e., family, other concerns not related to work) with [subject’s area]?
   a. Is that how you did it? If not, how is your current perspective different?
      Importance of other kinds of life skills?
      Relative importance of career in early or later life?

Peers and Colleagues
1. At any time in your life, have your peers been particularly influential in shaping your personal and professional identity?
2. In what way(s) have colleagues been important for your personal and professional identity and success?

Family
1. In what way(s) do you think your family background was special in helping you to become the person you are?
3. In what way(s) have your spouse and children influenced your goals and career?

Part C: Working Habits/Insights
1. Where do the ideas for your work generally come from?
   a. From: Reading? Others? Your own previous work? Life experiences?
   b. What determines (how do you decide) what project or problem you turn to when one is completed?
   c. Have there been times when it’s been difficult to decide what to do next? What do you do?

2. How important is rationality versus intuition to your work? Describe.
   a. Are there different styles in your work (e.g., one more “rational” and the other more “intuitive”)?
   b. Do you think it’s important to “go with your hunches” or “trust your instincts”? Or are these usually wrong/misleading?
   c. Do you have better success with a methodical, rigorous approach to your work?
   d. Do you think about work during leisure time? E.g., did you ever have any important insights during this “off” time?
   e. How many hours of sleep do you usually get? Do you tend to do your best work early in the morning or late at night?
   f. Have you ever had a useful idea while lying in bed, or in a dream?

3. How do you go about developing an idea/project?
   a. Do you write rough drafts? Outlines? How often do you rewrite?
   b. Do you publish your work right away or wait awhile?
4. Can you describe your working methods?
   a. How do you decide what mail to answer, interviews to do, etc.?
   b. Do you prefer to work alone or in a team?

5. Overall, how is the way you go about your work different now from the way you worked twenty years ago?
   a. What if any changes have there been over the years in the intensity of your involvement in [subject’s area]?
   b. What about changes in the way you think and feel about it?

6. Have you experienced a paradigm change in your work? Describe.

<table>
<thead>
<tr>
<th>Part D: Attentional Structures and Dynamics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. At present, what task or challenge do you see as the most important for you?</td>
</tr>
<tr>
<td>a. Is that what takes up most of your time and energy? If not, what does?</td>
</tr>
<tr>
<td>2. What do you do about this? [probe for field/domain reflection].</td>
</tr>
<tr>
<td>3. Do you do this primarily because of a sense of responsibility, or because you enjoy doing this? Describe.</td>
</tr>
<tr>
<td>4. Are you planning to make any changes in how actively you work in [subject’s area]?</td>
</tr>
<tr>
<td>5. If we had spoken to you thirty years ago, what different views of the world and yourself would you have had?</td>
</tr>
<tr>
<td>6. Have there been some personal goals that have been especially meaningful to you over your career? If yes, could we talk about some of the most significant?</td>
</tr>
<tr>
<td>a. How did your interest in this goal begin?</td>
</tr>
<tr>
<td>b. How did it develop over time? (Now?)</td>
</tr>
<tr>
<td>c. How important was this goal to your creative accomplishments?</td>
</tr>
</tbody>
</table>
APPENDIX B:

Student Interview Questions Adapted from Csikszentmihalyi (1996)

<table>
<thead>
<tr>
<th>Part A: Educational Experiences and Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Of all the things you’ve done this year in science class, what stands out to you?</td>
</tr>
<tr>
<td>2. Of all the things you’ve done this year in science class, what are you most proud of?</td>
</tr>
<tr>
<td>3. Can you tell me about a time something got really hard for you? What made it hard?</td>
</tr>
<tr>
<td>How did you handle it?</td>
</tr>
<tr>
<td>4. What factors supported your work?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Part B: Working Habits/Insights</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Where do your ideas usually come from? Give an example.</td>
</tr>
<tr>
<td>2. How do you go about developing your ideas? Give me an example.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part C: Relationships</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Panelists</td>
</tr>
<tr>
<td>a. In what ways was presenting to the panelists valuable?</td>
</tr>
<tr>
<td>2. Teacher</td>
</tr>
<tr>
<td>a. What role did the teacher play in your learning?</td>
</tr>
<tr>
<td>b. In what ways could the teacher have helped you learn more?</td>
</tr>
<tr>
<td>3. Peers and Colleagues</td>
</tr>
<tr>
<td>a. What ways were your peers important for your learning science?</td>
</tr>
<tr>
<td>4. Family</td>
</tr>
<tr>
<td>a. In what ways did your family help you learn science?</td>
</tr>
<tr>
<td>b. Did you do any science outside of school this year? If so, did you do it with family, peers, siblings, or alone?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part D: Attentional Structures and Dynamics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. You’ve done a lot of STEM this year. What is something you are curious about and really want to learn more about?</td>
</tr>
<tr>
<td>2. Do you see yourself investigating anything on your own outside of school? If so, what might you investigate?</td>
</tr>
</tbody>
</table>
APPENDIX C:
Invention and Innovation Design Process

Bug List:
Write your bug list in your design notebook.
What is something that really bugs (annoys) you?
What chore could be made more interesting or easier?
What is something that could be improved to
make it better/easier to use?
What is a problem that needs to be solved to
make the world a better place?
What is a problem you see other people having
that could be made better with an invention or
innovation?
Survey family and friends to find out what bugs them.
Survey school and community to find out what bugs
them. Keep adding to your bug list to help you with future projects.

Problem Statement:
Write your problem statement in your design notebook.
What is a problem that needs to be solved?
Your problem statement should tell something
that bugs you or someone else + explain why it bugs you or someone else.
(Examples: “Cricket” is not a problem, but “Noises crickets make
keep me awake at night” and then “I am left the next day” is a
cricket. “Carrying things” is not a problem, but “Dropping things
while you carry them and they break or you get embarrassed” is a
problem)
The problems could be either social problems or physical items you
need to invent or improve (Innovate) a solution
They need to be do-able, not already solved, and not simply
answered (to do list, telling someone)

Value of Solving the
Problem:
Write the value of solving the problem
down in your design notebook.
Why would it be valuable to
solve the problem?
Why is this problem worth
spending time and resources to
solve?

Background Research on
Problem:
What research do you need to do to understand
your problem better?
What expert can you connect with to talk about
your idea?
What knowledge and skills are needed to solve
your problem?
Write the answers to these questions and the information you
gather in your design notebook.

Customer Interview and Feedback:
Interview people who might want, use, and benefit from your
solution to find out if your problem is actually a problem for many
people.

In the interview, ask your potential customer:
Do you have this problem? If you think it is important to solve this problem? How do you
think this problem should be solved?
Write the information you gather in your design notebook.

If your problem is not a problem for most people then you need to think of a
new/different problem to solve. Pivot. You don’t want to spend time and
time trying to solve a problem that isn’t a problem for others. You
also don’t want to take resources (time, money, talent, energy) away from
another problem that really needs solving.

Solutions:
Step 1:
What ideas do you have to solve this problem?
What is your best idea for solving the problem?
Does your idea for a solution have value? Is it worth spending time to develop
(create, make, whatever) your solution?
Is it a new or a solution that already exists? Is your idea for a solution
do-able, new, and not a simple answer (to do list, telling someone)?
Does your idea harm human health or the environment in any way? (For example,
does your idea cause pollution or does your idea allow people to become active and therefore less healthy?)
Step 2: Write a clear and detailed description of your solution in your design
notebook. Include a detailed and labeled diagram with your written description.
(What kind of prototype do you need to create to get your idea across the best?)
Step 3: Is your idea valuable to your customer? (You need to interview customers
again to find out what they think of your idea for a solution. Ask for feedback on
how they think your solution could be improved. Write the information you
gather in your design notebook.)

Next Steps:
Who can you connect with to help move your
idea forward?
What information do you need to include in
your presentation to your potential
partner(s)?
What skills do you need
to practice in order to
present yourself and
your idea in the best
way?
Do you have a high
quality prototype to help
with your explanation?

Adapted from STEM Innovator,
University of Iowa (2015)
APPENDIX D:

STEM Innovator Canvas

<table>
<thead>
<tr>
<th>Key Partners (Who)</th>
<th>Key Activities (Do)</th>
<th>Value Propositions (Solutions &amp; Value)</th>
<th>Customer Relationships (How)</th>
<th>Customer Segments (Who)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition: Alliances with other people, groups, companies that work with you to solve the problem.</td>
<td>Definition: The most important action here is to perform an activity that solves the problem.</td>
<td>Definition: The solution that creates value for your specific customer.</td>
<td>Definition: The connections you establish and maintain with specific customer segments.</td>
<td>Definition: Groups of potential customers determined by common needs, behaviors, attributes, and other characteristics.</td>
</tr>
<tr>
<td>Who are the key partners who will provide key activities and/or key resources to help you solve the problem?</td>
<td>How do you approach the solution?</td>
<td>Solutions: What is your minimum viable solution? What simple message or slogan allows you to communicate your solution to customers?</td>
<td>Are you targeting, keeping, or growing customers?</td>
<td>What type of customer relationship does each customer segment expect?</td>
</tr>
<tr>
<td>What key activities and/or key resources do key partners provide to solve the problem?</td>
<td>What key activities drive the value propositions required to meet the needs of the customer?</td>
<td>Examples: Value, ease of use, price, quality, reputation, etc.</td>
<td>What are the main drivers you use to retain customers?</td>
<td>1. Personalized interactions 2. Value-based marketing 3. Exceptional service 4. Social media engagement 5. Loyalty programs 6. Referral programs</td>
</tr>
<tr>
<td>What are the benefits of partnering?</td>
<td>What key activities are required relating to customer relationships?</td>
<td>Revenue Streams: How will you collect payment?</td>
<td>What are the main drivers you use to attract new customers?</td>
<td>Customer Discovery (Feedback): How will you find new customers?</td>
</tr>
<tr>
<td>How will you build a relationship with your key partners?</td>
<td>Customer Discovery: What will you do to foster customer loyalty?</td>
<td>Examples: Sales, Marketing, E-commerce, etc.</td>
<td>Customer Discovery: How will you gather feedback from your customers?</td>
<td>Feedback collected from customers and used to determine next steps.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key Resources (What)</th>
<th>Problem Statement:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition: The most important assets required to solve the problem.</td>
<td></td>
</tr>
<tr>
<td>What key resources do the value propositions require to meet the needs of the customer?</td>
<td></td>
</tr>
<tr>
<td>What key resources are required relating to customer relationships?</td>
<td></td>
</tr>
<tr>
<td>Examples: Intellectual Property, Human Resources, Information Technology, etc.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Channels (How)</th>
<th>Customer Discovery (Feedback):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition: How will you communicate with and reach customers to deliver your value proposition?</td>
<td>Definitions: Feedback collected from customers and used to determine next steps.</td>
</tr>
<tr>
<td>Channels: How will you share your solution?</td>
<td>Feedback collected from customers and used to determine next steps.</td>
</tr>
<tr>
<td>How will you connect your solution to your community?</td>
<td>Customer Discovery: How will you gather feedback from your customers?</td>
</tr>
<tr>
<td>P2P/Peer-to-Peer, Innovation Economy, Research/Development, etc.</td>
<td>Customer Discovery: How will you gather feedback from your customers?</td>
</tr>
<tr>
<td>Technical Research, Journal Article, Media, Social Media, Blog, TV, Podcast, etc.</td>
<td>Feedback collected from customers and used to determine next steps.</td>
</tr>
<tr>
<td>Examples: Channels: How will you share your solution?</td>
<td>Feedback collected from customers and used to determine next steps.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost Structure (How)</th>
<th>Revenue Streams (How)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition: All costs incurred to operate your business.</td>
<td>Definition: The money a company generates from sales of the product/service.</td>
</tr>
<tr>
<td>What are the costs your business incurs through key activities, resources, and partners to operate?</td>
<td></td>
</tr>
<tr>
<td>A breakdown of costs in order to operate by your business cost driver or value driver.</td>
<td></td>
</tr>
<tr>
<td>Types of Cost Structures: Fixed, Variable, Fixed, Variable, etc.</td>
<td>Types of Revenue Streams: Product/Service, Subscription, etc.</td>
</tr>
<tr>
<td>E.g., labor, materials, facilities, IT, advertising, etc.</td>
<td></td>
</tr>
<tr>
<td>Revenue Streams: How will you make money?</td>
<td></td>
</tr>
<tr>
<td>Sales, Marketing, E-commerce, etc.</td>
<td></td>
</tr>
</tbody>
</table>

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Commercialize-Patent-Invent-Pivot-Design-Innovate

Innovate-Design-Pivot-Invent-Patent-Commercialize

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Adapted from Alex Osterwalder, Business Model Generation

The University of Iowa
APPENDIX E:

Alex Osterwalder Business Model Generation Canvas