Exploring Aesthetic Experiences in the Undergraduate General Education Science Classroom

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ABSTRACT

Citizens must have a minimal level of STEM-literacy to work alongside scientists to tackle both current and future global challenges. How can general education, the one piece of the undergraduate experience every student completes, contribute to this development? And science learning is dependent on having transformative aesthetic experiences in the science classroom. These memorable experiences involve powerful connection between students and the world around them. If these types of experiences are necessary for science learning and growth, are students in introductory science courses having them? If so, what relationship might they have with students' desires to pursue further science study?

This dissertation explores these questions through two manuscripts. The first, a theoretical piece published in the *Journal of General Education* in 2015, argues that non-STEM students must have transformative aesthetic experiences in their undergraduate general education science course to develop the level of understanding needed to engage with challenging scientific issues in the future. This claim is substantiated by bringing together the work of Dewey and Deweyan scholars on the nature and impact of aesthetic experiences in science and science education with the general education reform efforts and desired outcomes for an informed and engaged citizenry.

The second manuscript, an empirical piece, explores the lived experience of non-STEM students in an introductory geosciences course. A phenomenological research methodology is deployed to capture the 'essence' of the lived experience of a STEM-philic student in general education science. In addition, Uhrmacher's CRISPA framework is used to analyze the

participants' most memorable course moments for the presence or absence of aesthetic experiences. In explication of the data, it shows that students are in fact having aesthetic experiences (or connecting to prior aesthetic experiences) and these experiences are related to their desires to pursue further STEM study.

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GENERAL AUDIENCE ABSTRACT

To work alongside scientists to tackle both current and future global challenges, citizens must have a minimal level of STEM-literacy. General education is the one piece of the undergraduate experience every student completes and, if done well, can contribute to the development of STEM-literacy. It is argued that science learning is dependent on students having transformative memorable aesthetic experiences in their courses. Questions that arise include: 1. If these experiences are so important, are students in introductory undergraduate science courses having these transformative aesthetic experiences? and 2. If so, what relationship might they have with students' desires to pursue further science study?

This dissertation explores these questions through two studies. The first argues that non-STEM students must have transformative aesthetic experiences in their undergraduate general education science course to develop the level of understanding needed to engage with challenging scientific issues in the future.

The second explores the lived experience of non-STEM students in an introductory geosciences course. The purpose is to capture the 'essence' of the lived experience of a STEM-philic student in general education science. It is shown that students are in fact having aesthetic experiences (or connecting to prior aesthetic experiences) and these experiences are related to their desires to pursue further STEM study.

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I owe a debt of gratitude to my wife, Laura Biscotte, for her support and sacrifice during the past decade of my graduate studies. I can only hope that one day I will be able to show her and my two kids, Carter and Miles, that these continued academic pursuits were worth the trouble… that lifelong learning is worth the trouble. I would also like to thank my parents, Mike and Dawn Biscotte, for the endless support and unconditional love they have shown me since childhood. Without this strong support system, I simply would not have finished.

Attributions

Bruce Uhrmacher of the Morgridge College of Education at the University of Denver, provided the framework on which much of this work is built. In addition, Dr. Uhrmacher provided feedback to strengthen the journal submission of Manuscript 1 and reviewed my analysis of student experiences using the CRISPA framework to add a degree of trustworthiness to Manuscript 2. John Chermak, professor of Geosciences at Virginia Tech, provided the inspiration and study site to complete Manuscript 2. Dr. Sandra Thomas and the members of the Center for Applied Phenomenological Research at the University of Tennessee provided group transcript reading and discussion services for Manuscript 2.

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Introduction to the Dissertation

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Background on General Education

According to the Yale faculty in 1828, a liberal education was distinct from a professional education in that it was meant to build "all the mental faculties" and reasoning skills to prepare the student for any event in life after college (Committee of the Corporation and the Academical Faculty, 1828). Even then, the university faculty recognized the university role in developing a well-rounded student and whole person, not just a trained professional, as evident from their report:

> On the other hand, he who is not only eminent in professional life, but has also a mind richly stored with general knowledge, has an elevation and dignity of character, which gives him a commanding influence in society, and a widely extended sphere of usefulness. His situation enables him to diffuse the light of science among all classes of the community. Is a man to have no other object than to obtain a living by professional pursuits? Has he not duties to perform to his family, to his fellow citizens, to his country…? (Committee of the Corporation and the Academical Faculty, 1828, p. 15)

This report is recognized as a result of the first official university debate about the purpose of general education science in relation to professional preparation. At the time, there was a demand to shed the subjects (e.g. Greek and Latin) with less practical value in the 'technological' workplace. Fast forward nearly 200 years. Now there is increased pressure on the undergraduate curriculum to improve the STEM workforce to improve global competitiveness. In 2012, the President's Council of Advisors on Science and Technology (PCAST) issued a report to answer President Obama's call for an increase of 1 million college students graduating with degrees in Science, Technology, Engineering, and Math (President's Council of Advisers on Science and Technology (PCAST), 2012). According to the report, students cite "uninspiring introductory courses" and "an unwelcome atmosphere from faculty" as reasons for abandoning pursuits of STEM degrees. Of the five recommendations listed in the report, the first two plead for better teaching practices, based on empirical evidence, and better laboratory experiences, moving from traditional to discovery-based models, once again putting the emphasis and weight of success on the shoulders of undergraduate faculty in the science. But with this much attention on STEM retention, who is neglected and at what cost?

In his book *Why Science?,* Trefil (2008) describes a "visible university" which has the goal of preparing all students to become educated citizenry and balanced intellectuals. This goal appears on the website, in the curriculum, on the syllabi. It closely aligns with the goals of the Yale faculty nearly 200 years ago. However, there is also an "invisible university" to which not every student has access. It is here that material is vertically aligned, professors sink hours into their work, and students are placed on a path towards scientific literacy. Trefil contends that, unfortunately, this invisible university only applies to majors within the colleges. The PCAST (2012) would argue that even STEM majors are not guaranteed this access (or results). Regardless, there is great conflict between the visible and invisible universities when it comes to time, effort, and resources. And now, as then, general education often loses out.

When discussing the role of science teaching at the university level, Trefil (2008) paints an unflattering picture where classes are poorly taught (especially science) and are given little attention compared to other purposes of the university, like scholarly research. This supports the findings of the President's Council of Advisers on Science and Technology (PCAST, 2012). However, what should be the student experience in those general education science courses? And in actuality, what is it? As Gaff (1983) recognized, the "students are conspicuous by their absence in the debate about General Education" (p. 51). These are the questions this dissertation seeks to explore and the lack of student perspective in discussions around general education is the limitation it hopes to overcome.

Impetus for the Research

Over the past three years as the Coordinator for General Education I have been intimately involved with each aspect of the campus-wide general education curriculum reform effort. Generally, this effort featured four broad steps. First, there was a recognition that the curriculum needed improvement. This call came from students, faculty on the general education curriculum committee, and administration and appeared in surveys, committee reports, and the strategic plan. A student survey conducted to gather student perspectives on the current curriculum at the studied institution (Hall, Culver, & Burge, 2010) revealed that 75% of students felt the outcome related to natural science was important, but only 63% felt at least satisfied by their academic opportunities to develop this outcome. Opportunities for improvement related to the structure (e.g. flexibility, alignment with major), perceived value (e.g. for graduation, employability), degree of effectiveness (e.g. opportunities for outcomes development, program assessment), and attention to modern skills and capacities (e.g. computational thinking). Ideas for making these improvements were culled from peer institutions and publications from national organizations like AAC&U.

Second, a curriculum was constructed and put through faculty governance. Teams of faculty met to draft the outcomes for each learning area (e.g. Reasoning in the Natural Sciences) and the guidelines for the more innovative structural components including general education minors and alternative mechanisms for completing the requirements (e.g. study abroad). During this curricular development period, key stakeholders across campus engaged in often passionate discussion about the nature of higher education, general education, and meeting these needs in the context of our large top-tier research land-grant institution. These groups included university, college, and departmental curriculum committees, faculty senate and other faculty led committees, advisers, student groups, administrative support units (e.g. center for teaching and learning), administration, governance commissions, and faculty involved with general education. The outcome teams discussed more specific curricular questions like 'what should every student know about science before they graduate?', 'what does it look like for a student to be able to reason scientifically?', and 'how will we know?'

Third, an implementation plan was drafted and put through governance. This document included guidelines for how a scientific reasoning course could be submitted to the program, how that instructor would score the level of student competence in scientific reasoning, and means of support available for those involved with the process. Finally, the implementation process began with faculty designing or redesigning courses to align with the new curriculum.

By request of the then Provost, the researcher had the opportunity to collect student opinions on the general education curriculum, specifically the science requirement. In the focus group discussions, some common themes emerged: students 1) had insightful perspectives about what practices supported their learning in science courses, 2) had very complex and nuanced views of how the institution (de)valued general education, and 3) were able to recall some memorable moments from their general education courses and how those moments impacted their personal and academic development. It was curious how the same student could identify the general education science requirement (or course or class period) as 'worthless' and a 'waste-of-time' but could then enthusiastically recall a story from a specific course that fundamentally changed the way he or she looked at the world. These focus groups seemed to unpack the claim supported by the student survey that there was a disconnect between 'the valued' and 'the experienced.' It seemed from the preliminary focus group data that in-depth study of the student experience in those general education courses, particularly the memorable experiences that may have transformed and inspired the student in meaningful ways, would prove fruitful. Thus, the research to follow explored the transformative student experiences in general education science course and resulted in the two manuscripts submitted here.

Aesthetic Experience in General Education: A Review of the Literature

The first manuscript includes the purpose for attending to general education science and a review of the relevant literature related to John Dewey's 'aesthetic experience' (Dewey, 1934). In *Art as Experience*, Dewey unpacks the idea that the work done by the artist in creating art is an immersive, transformative, transactional engagement with an object yielding personal growth. He contends that any moment can include this physical, mental, and emotional engagement as long as the conditions allow for anticipation, continuity, and fulfillment. Dewey doesn't mention the word 'education' in his description of '*an* experience,' however Deweyan scholars have since extended this theoretical framework to teaching and learning in the science classroom, the focus of this first manuscript. Questions addressed in this theoretical piece include:

A. What are aesthetic experiences?
B. What do they look like in the science classroom?
C. How important is having aesthetic experiences for learning in the science classroom?
D. How can instructors offer opportunities for students to have these experiences?

The manuscript ends with pedagogical implications for teaching and learning in the classroom and a call for further research on the topic which includes the need for empirical exploration of the nature of aesthetic experiences in the classroom, the focus of the second manuscript.

The Lived Aesthetic Experience of Students in a General Education Science Course

The second manuscript explores the concrete lived experience of STEM-philic students in an introductory geosciences course. 'STEM-philic' students a) are non-STEM majors, b) are taking the course solely to meet general education requirements, and c) express the desire to pursue further STEM study even if they don't have to. The manuscript begins with the purpose of studying the student experience in general education and a relevant review of the literature related to the aesthetic experience. Next, a description of the phenomenological research method utilized during the study is provided with specific attention to the components of an aesthetic experience outlined in the CRISPA framework (Uhrmacher, 2009). This methodology allows for exploration of the lived experience of 'STEM-philic' students in general education science and of the research questions used to guide the study:

A. Is there a relationship between students' perceptions of having aesthetic experiences in the general education STEM course and pursuing further STEM study?
    a. Do STEM-philic students perceive that they have had aesthetic experiences in the course and if so, have these experiences impacted their desire to pursue further STEM study?
    b. In these perceived aesthetic experiences, is there presence or absence of the dimensions of aesthetic experience (CRISPA)?

Following the phenomenological methodology an explication of the focus group and semi-structured interview data provides the 'essence' of the lived experience of STEM-philic students in a general education science course. This is followed by a more intentional analysis through the CRISPA framework to uncover the presence and nature of aesthetic experiences undergone by the students. Next, a discussion of the research questions is included followed by the implications of the results and a description of future research opportunities related to the topic.

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The Necessity of Teaching for Aesthetic Learning Experiences in Undergraduate General Education Science

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ABSTRACT

Students should have aesthetic experiences to be fully engaged in science learning at any level. A general education science instructor can foster opportunities for aesthetic educative learning experiences enabling student growth. Drawing on the work of John Dewey and expanding on others in the field, Uhrmacher identifies the characteristics of the aesthetic experience, which include, but are not limited to, connections, active engagement, sensory experience, perceptivity, risk taking, and imagination. I argue that if instructors are not attending to these aesthetic characteristics, then students are not doing (learning) science and will therefore fail to meet any valuable outcomes identified for general education science.

Reforming General Education for Increased Aesthetic Experiences

Are You or a Loved One Suffering from General Education Reform?

In 2008, educators at nearly 90 percent of universities were in the process of reforming their general education programs (Hart Research Associates, 2009). In nearly 80 percent of these cases, the stakeholders surveyed had either reformed the old program or introduced a new one based on clear and measurable learning outcomes for all undergraduates with an increased emphasis on "engaged learning practices" and rigorous assessment practices to ensure that they are being met. These higher education professionals have likely been involved in the reform process through committees, conferences, conversations, policy writing, professional development, or thoughtful reflection on the purpose and practice of general education. But do the general education science outcomes declared by the institution, along with the resulting program structure, assessments, and pedagogies to meet and evaluate the outcomes, enable opportunities for aesthetic experiences for students in the science classroom? Do the outcomes allow for these memorable, deeply engaging, transformative experiences that contain "joy and sorrow" (Wickman, 2006, p. 148), "surrender, receptivity, and suffering" (Wong, 2007, p. 204), and come to fruition/consummation (Dewey, 1934)? As a number of works highlight,[1] scientists have sensory-driven and engaged experiences when engrossed in the beauty and wonder of their research (Flannery, 1991), so a student of science should participate in similar experiences to do (learn) science.

Just Listen to These Testimonials

Students want general education to be useful, to "open their eyes to the world," and to help them be well-rounded members of society. However, it does not always have this effect. In one of the student focus groups I have conducted to gather the student perspective on nonmajor science courses, one student art major reflected on her experience in an introductory science course with the sobering comment, "We may as well have not even been in the room." Other humbling phrases that have come up in both focus groups and interviews include "awful" (not awe-full), "worthless," and "same thing every day," often said with cringed faces and shaking heads. Yet other students have come to "appreciate science" and gain "interest in the world and how it works" or even pick up a minor in science based on a wonderful class with an "excited, passionate" instructor. Still, others have been unable to recall the science course they have taken at all. How could classes in the same building offered to meet the same general education course requirements with the same defined skills and knowledge provoke such varied responses?

Poignant student perceptions have served as inspiration for this philosophical work to refocus the conversation and issue a simple challenge. If an instructor is not enabling, or worse, is disabling, aesthetic experiences in the classroom, then he or she will fail to meet the learning outcomes or goals the institution has set for scientific literacy (or reasoning or thinking or learning). I contend that if students are participating in anesthetic experiences, the miseducation that interferes with and stunts growth, they will continue to remain as scientifically illiterate as their non-college-educated counterparts after graduation (Impey, Buxner, Antonellis, Johnson, & King, 2011) and perhaps, scarier still, come to *hate* science. These are unintended consequences that the reader (the faculty member, administrator, stakeholder), I (a coordinator of university general education), and we (citizens in a democratic nation) cannot afford.

But We Are Doing All We Can . . .

Perhaps an institution plans to focus general education science courses on core concepts, rather than content scientists already know, as Read (2013) suggests. Or the institution plans to offer interesting, nonsurvey thematic courses with an embedded science literacy assessment to provide feedback on the effectiveness of the science curriculum, as Waldo (2014) has done. The institutional plan may call for more "hands-on/minds-on," student-centered, or active learning approaches to engage students in learning. Local stakeholders may be trying to answer the president's call to produce one million new science, technology, engineering, and mathematics graduates by improving the perceived "uninspiring introductory courses" and "unwelcome atmosphere from faculty" that students cite as reasons for bailing on the pursuit of such degrees (President's Council of Advisers on Science and Technology, 2012). I myself am currently working as a coordinator and reformer of a general education program designed to meet all of these arguably noble and necessary goals for any course, program, or institution.

But regardless of the outcomes for, assessments in, and structure of the general education program, as valid and productive as they may be, students in nonmajor science courses must have the same opportunity for aesthetic experiences as those in major courses for any learning to occur. Students of the humanities, taking one or two science courses simply to meet the program requirement, must do science with the same aesthetic enjoyment they experience with subjects in their own discipline. And scientists must bring the same aesthetic understanding of the beauty of science that they experience in their research to their instruction in the classroom (Girod, 2007) (Girod, 2007). Only then can learning science become the means for a life filled with meaningful experiences: dramatic, memorable events anticipated and consummated to fulfillment (Wong, Pugh, & the Dewey Ideas Group at Michigan State University, 2001), arguably the ultimate goal of a successful general education science program.

Research on Aesthetics in Science Education

Dewey and the Dewey-Inspired Aesthetic Experience

So what are aesthetic experiences? As Dewey proposes in *Art as Experience* (1934), artistic (production) and aesthetic appreciation ("perception and enjoyment") cannot be separated. Perception is in itself a creation of an experience. The perceived work of art (science) is the same as doing and undergoing (suffering), moving forward to an intent or "end-in-view." There is passion, sensation, and anticipation of what is to come that cannot be separated from the doing, the making of something new. There is emotion, and this emotion is channeled and directed through the work. Aesthetic experiences "can be thought of, indeed they are, dramatic events" (Wong et al., 2001, p. 320). There is an organic relationship, not a dualism, between a person and his or her environment, and both come out different from an experience (Wong, 2007).

Aesthetic experiences, though often hard to identify (Uhrmacher, 2009), exist on a continuum between a short but memorable moment, such as a meal or a chess game, and an "aha" or "wow" experience that can change your life and outlook on the world. There exists no duality between the rational and irrational, cognitive and emotional (Wong, 2007). To make sense of and find meaning in an experience, the "aesthetic and efferent are inextricably related to one another" (p. 207). Emotion is necessary to make an "experience . . . continuous, so that development occurs" (Alexander, 1987, p. 222). There is no foreground without the background (Garrison, 1996). Once these dualisms are broken down, the problematic nature of creating learning goals and implementing pedagogies that lack attention to (or exclude) aesthetics is evident.

Yeah, but what are they? Aesthetic experiences are framed by anticipation, continuity, and consummation (Dewey, 1934). As Jackson (1998) summarizes, these experiences have a completeness, a uniqueness, and a unifying emotion that holds them together. A person will be engaged in the experience "through intelligent action" (Alexander, 1987, p. 186) and activity, building on his or her prior experiences and setting the stage for future experiences as the experience "realizes the sense of meaning and value as deeply as possible" (p. 186). And only after the experience has come to consummation, a marked end to the development, can the person reflect back and recognize it as having the unity of an experience, not to be forgotten (Dewey, 1934). Participants in an aesthetic experience do not wander forward aimlessly; nor do they move with repetitive robotic precision. They do not hurry; nor do they move so slowly as to invite the distractions common to our lives and classrooms. They are not overcome with passion or driven solely by action, as these are balanced in the work to perceive and create.

While producing, the artist (participant) does not just observe but, rather, perceives the world through advancing "active exploration" (Alexander, 1987, p. 197). The senses and intellect work in tandem with curiosity, wonder, and interest, such that one's "consciousness comes to inhabit the world" (p. 197). Otherwise, there is a risk of seeing the world as stale, lacking aesthetics. If a person rushes to complete as much as possible in the shortest period of time, the result will be superficial, surface experiences, leaving little time for consummation, let alone the learning that comes from reflection on the experience (Wong, 2007). For Dewey (1934), the enemy to aesthetic experience is monotony and the "humdrum," "loose ends," and conventionality. The experience that lacks continuity, fulfillment, and consummation is not "*an* experience." Learning is absent; growth is stunted. The experience is anesthetic or even antiaesthetic. This is why preset syllabi and phrases such as "cover the material" and "we don't have time" carry such danger and risk for disabling aesthetic experiences.

Also, aesthetic experiences are continuous with and transformative on both the cognitive aspects of science (learning the facts and principles) and the prior scientific and nonscientific experiences of the students (Wickman, 2006). In general, aesthetic experiences allow for "recurrent patterns of action, which could be said to form habits" (pp. 136–37). It is this key element of aesthetic experience that allows for the continuity of prior student experiences from within and outside of the classroom to everyday life, one of the primary goals of teaching for transformative aesthetic experiences (Pugh, 2004) and of doing science in general.

Aesthetics cannot be teased apart from science.[2] In fact, as Wickman (2006) contends, "without aesthetic experiences, science or science education—or any practice for that matter—will stop" (p. 148) and arguably may never start. Aesthetic experiences are the way we come to know science and apply it to the world around us. And this knowing does not come easy. In our world, one that is neither in pure constant flux nor complete and ended, there is anticipation and struggle, beauty and ugliness, "joy and sorrow" (p. 148), which move experiences forward to consummation. Only when these opportunities for undergoing are provided can a student move forward and grow. Otherwise, we are miseducators, curtailing student growth and negatively impacting their very identity.

Unfortunately, too often the undergraduate general education science class has become an environment without aesthetic experiences, without genuine science, without growth. Through aesthetic experiences, students become intimately intertwined with science concepts, to see the possibilities of participating in science and to learn how to act appropriately in science (Wickman, 2006). Therefore, as Per-Olof Wickman found in his explorations of the college science lab, aesthetic experiences are transformative and normative experiences.[3] If students do not participate in these experiences, they cannot see themselves as participants in science and instead see themselves as outside observers. Students are left feeling as though, as more than one student expressed to me, they are "not science people," and the university has offered no opportunity to challenge that notion, just reinforce it. Having defined aesthetic experiences for science education, we can explore ways to foster more of them in the science classroom.

Pedagogical Implications of Aesthetics in Science Education

OK, I want to teach for aesthetic experiences, but I don't know how. Aesthetic experiences cannot simply be added to the curriculum to make the content more accessible to student conceptual understanding or to sugarcoat the learning (Wickman, 2006; Wong, 2007). As Wong (2007) points out, there is "surrender, receptivity, and suffering" that places this undergoing far beyond simply doing or getting a taste of the subject. A person acts on the world, and the world acts back, where both come out different (p. 204). Regardless of the identified outcomes of the class, teachers can increase deep student engagement with the curriculum and "turn their ordinary learning experiences into aesthetic ones" by attending to and expanding upon six characteristics that allow for more opportunities for aesthetic learning experiences: connections, active engagement, sensory experience, perceptivity, risk taking, and imagination (Uhrmacher, 2009, p. 614). A student undergoing an aesthetic experience connects and actively engages with an object in his or her environment by perceiving, not just recognizing, the object through sensory experience and venturing into the unknown by using imagination and taking risks that lead to many rich and often surprising connections. A teacher should carefully consider these characteristics associated with aesthetic experiences both in the lesson planning phase and in the moment to increase the opportunities for aesthetic learning experiences (Uhrmacher, 2009). Again, this is not a how-to guide but offers a place to start.

In a study on the aesthetic understanding of fourth-grade students in an urban elementary school, Girod, Rau, and Schepige (2003) identified five practices an instructor can employ to restructure the curriculum to foster aesthetic understanding: (1) recontextualize (craft) the concepts within their exciting history or origin story so that students “feel like detectives unraveling a mystery, not like cooks following a recipe” (Wong, 2007, p. 211), building anticipation; (2) ask “what if” questions to spur and inspire creativity and alternative thinking; (3) have students “resee” everyday objects for their inherent detail; (4) model the appreciation, value, and artistic connection of transformative ideas; and (5) guide students through this new way of coming to know science and their place within it (identity and self-efficacy). Here, the instructor is like an “artist in a studio trying to shape curricular ideas and experiences for children in artistically pleasing and aesthetic ways” to create an environment that enables aesthetic experiences (Girod et al., 2003, p. 579).

In addition to creating a good lesson plan, the instructor has a primary responsibility of monitoring students and moving them forward in their learning or growth (Dewey, 1934) during class time. Jakobson and Wickman (2008) identify instances where elementary school students and their teacher use aesthetic judgments/language to communicate with each other in anticipation and/or consummation of an experience, as part of a whole hands-on activity. The positive aesthetic judgments serve not only to express pleasure in an observation or exchange but also to move the activity forward, expressing continuity and transformation from prior experience. The teacher can recognize negative judgments as a sign that the experience could come to a stop before consummation and thus ask the right questions to get the activity moving toward fulfillment again. At this point, the instructor can guide or model how to proceed to reach fulfillment of the aesthetic experience (Wickman, 2006).

Well, does it work? Girod, Twyman, and Wojcikiewicz (2010) investigated the effects of teaching science with goals consistent with a cognitive, rational pedagogical framework compared with teaching for transformative, aesthetic experiences. In a quasi-experimental study, the teacher taught using best practices for a cognitive approach to the conceptual understanding of weather, matter, and erosion (e.g., frequent quizzing, proper vocabulary usage, inquiry labs) in the control classroom. In the treatment or experimental classroom, this teacher held goals and used practices consistent with garnering transformative, aesthetic experiences.

In this aesthetically rich setting, the instructor focused on the big ideas of the material rather than the isolated definitions (Girod et al., 2010). He asked the students to use the material learned in class to "resee" their everyday world. Through storytelling and powerful images and statistics, he garnered a sense of wonderment in the students, an identified goal of his course. Students were able to personalize the information by relating it to their own experiences. And the teacher modeled passion and love of the subject. With these changes, students were able to do more than just learn the content. Although students in both classes learned the material, students in the treatment class "were drawn to wonder, tell others, and see the world through new eyes" (p. 811). Students were different in the world; a transaction and transformative experience had occurred. These are the types of transformations needed from non-science-major students so that they feel a part of science, not separate from it; students are participants in and perceivers of the world, not mere passive observers.

Conclusion

Fostering Aesthetic Experiences in General Education Science

It's just too hard. There are certainly challenges to fostering opportunities for aesthetic experiences in the general education science classroom. There is a historical precedent for anesthetic experiences in general education science courses. Over a half century ago, Sidney French (Watson & Cohen, 1952) from Colgate expressed the challenges of teaching science in general education at that time: "As teachers we have all witnessed the sad spectacle of students who through some arbitrary requirement or mistaken enthusiasm found themselves in a science course for which they developed loathing, contempt, or fear" (p. 17). For better or worse, since its inception, the goals of general education science have often echoed those of the public, policy makers, and scientists for America at the time, leaving a revolving door of purposes and methods to achieve them. In *Quest for Common Learning*, Boyer and Levine (1981) describe general education as a spare room in the house of higher education. Unlike the major and the free electives, general education has often had an unclear identity with unclear ownership; this has led to disagreement over its purpose, its maintenance, and its contents. It is a place to keep grand initiatives such as "Writing Across the Curriculum" or "Integrated/Interdisciplinary Science" experiences, but like any spare room, it is often neglected or forgotten as soon as the next challenge comes along. General education programs end up being "simply storage spaces, places to keep odds and ends" (p. 3). The metaphor of the "spare room" certainly does not paint a picture of a program built with learning as its first priority, but we have the ability to transform this space into one of fulfilling, memorable experiences and learning.

I can do it! French took a look in the mirror and asked the hard question of whether "perhaps it was our science *teaching* that was at fault" (Watson & Cohen, 1952, p. 17). If we are not teaching for aesthetic experiences, then it is our fault that students fail to learn, or even come to hate or fear, science. Despite the presence of structural challenges and ever-encroaching accountability measures, we still have academic freedom, support, and guidance. According to the Association of American Colleges and Universities (2002), a national organization dedicated to improving higher education, general education is simply defined as the portion of university studies "shared by all students" (p. 25) to provide the breadth of experience in multiple subjects and develop "important intellectual and civic capacities." (p.25) With a broad definition like this, there is freedom to explore the classroom pedagogies that enable the aesthetic experiences necessary to learn science at any grade or age (Wickman, 2006) and develop those very capacities.

Basically, if instructors recognize that "teaching and learning for aesthetic understanding represents science education at its very best," then they will offer as many opportunities for occurrence as possible (Girod et al., 2003, p. 585). The rewards are worth the risk. Students use aesthetic judgments to determine what belongs in, and whether they belong in, the science classroom (Jakobson & Wickman, 2008). Teachers can recognize aesthetic judgments to keep students moving forward. In addition, teaching for transformative aesthetic experiences yields in students an increased conceptual understanding, retention a month later, science identity and efficacy, and interest in science inside and outside of the classroom over a cognitive, rational approach (Girod et al., 2010). Aesthetic values in science education can liberate the students, serving as the "best road to scientific and technological literacy" (Desautels, Fleury, & Garrison, 2002).

Exploring "living ideas" (Pugh & Girod, 2007), rather than regurgitating fixed concepts, is central in facilitating transformative aesthetic experiences. The teacher's role is to transform the concepts (provided by state standards, curriculum guides, textbooks, or syllabi) into ideas that students can engage with and actively apply in their everyday lives (Pugh, 2004). Good teaching involves incorporating the drama and emotion inherent in science to build anticipation on which the students can act (Wong et al., 2001). Without this building emotion, "there is no involvement, no care, and so no deep or significant response" (Alexander, 1987, p. 222). By modeling actions such as "reseeing" objects in the world and the power of transformative ideas, the instructor can scaffold the pursuit of aesthetic understanding, helping students reach the consummation of *an* experience (Girod et al., 2003). This sets the stage for reflection, an important and neglected strategy in its own right (Jordan, Rousch, & Howe, 2006) but truly pivotal to the learning process following an aesthetic experience (Dewey, 1934).

As James Trefil professes in his book *Why Science?* (2008), at the end of the day we are "trying to produce citizens who are scientifically literate" (p. ix). It is the responsibility of the university to do more than just train the next scientist or engineer and to consider how "average citizens actually use science" (p. 148) and offer aesthetic experiences to foster student competency and efficacy to engage in their world. Everyone involved in reform efforts is making changes with the hopes of inciting a revolution with "introductory science courses [that] would engage students and encourage them to take more science classes" from faculty who "bring rigor and enthusiasm of research to their teaching" (DeHaan, 2005, p. 267). Teaching for aesthetic experiences can enable opportunities for the consummation of these outcomes. This is not meant as a silver bullet or a "Gen Ed in a Box" program. This is education. Supplies are limitless; order today.

Future Research: But Wait, There's More!

Teaching for aesthetic experiences is critical to learning science in both K–12 and college environments, but further empirical research is necessary to explore best practices and pedagogies that foster them in the undergraduate science classroom. In their review of the literature on the relationship between student learning and out-of-school experiences, Pugh and Bergin (2005) recognize a real gap in the research exploring "one of the key purposes of schooling—what students do with their learning outside of school" (p. 15). Although studies conducted from the perspectives of transfers, external/informal learning environments, interest, and transformative education exist, they rarely focus on the transfer of knowledge or enrichment of experience beyond the walls of the classroom or school. Aesthetic transformative education can provide the framework so that faculty can "select the kind of present experiences that live fruitfully and creatively in subsequent experiences," the ultimate goal of undergraduate general education and a concept ripe for further inquiry (Dewey, 1938, p. 28).

If aesthetics are an integral part of students' understanding of science, how are aesthetics actually "validated, supported, and used in their education" (Desautels et al., 2002, p. 262)? Challenges in teaching for aesthetic experiences include overcoming students' prior training in playing the school game rather than pursuing learning for learning's sake with all the time, reflection, and struggle necessary to do so. Can teaching for aesthetic experience and understanding enhance existing pedagogical strategies for engaging students and increasing conceptual understanding, such as using myths (Prischmann, Steffan, & Anelli, 2009), problem-based learning (Keller, 2002), or videos and small groups (Gill, 2011)? With the themes for fostering an aesthetic experience identified, future research is necessary to determine whether teaching for aesthetic experience increases student joy in learning, meaning making, and creativity in any topic outside of the major, not just science (Uhrmacher, 2009).

Notes

1. For examples of these interpretations, see *Truth and Beauty: Aesthetics and Motivations in Science* (Chandrasekhar, 1987) and *"Surely You're Joking, Mr. Feynman!" Adventures of a Curious Character* (Feynman, 1985), among others cited by Flannery (1991), as well as an empirical study of social scientists by Eisner and Powell (2002).

2. If there is any doubt at this point, read *The Annotated and Illustrated Double Helix* by James Watson (2012).

3. For a more complete discussion of the aesthetic experiences of college students and an example of a research methodology used in the field, read *Aesthetic Experience in Science Education* by Per-Olof Wickman (2006).

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"Wow. That's real. That really happened.": A Phenomenological Study of the Lived Experience of Non-STEM Major Students in an Introductory General Education Geosciences Course

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“Wow. That’s real. That really happened.”: A Phenomenological Study of the Lived Experience of Non-STEM Major Students in an Introductory General Education Geosciences Course

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ABSTRACT

To address the wicked problems and global issues that face the environment and humanity, it will take both the efforts of STEM professionals and also the engagement of a STEM-literate public. Engagement of ‘STEM-philic’ individuals, those students who may not have STEM degrees but have the desire to pursue further STEM study, in general education science is a crucial goal in achieving this informed, STEM-literate citizenry. It is suggested that for these students to learn and engage with science, they must have transformative aesthetic experiences in their undergraduate general education sciences courses. But it is unclear whether students are having these experiences and to what extent they impact their desires for further STEM study. To explore this, a phenomenological study was conducted to explore the lived experience of non-STEM students in introductory general education STEM courses.

In the explication of the data it was found that students needed to see the relevance and impact of course topics and issues to make personal connections to themselves, other people, or the world around them. With the knowledge gained in the classroom, students were able to enter and elevate conversations with classmates, friends, or family. Seeds for further inquiry were planted. Aesthetic experiences as defined by the CRISPA framework were perceived, many of which aligned neatly with the participants’ future pursuits of STEM study. It was inferred that instructors used ‘sparks’ like telling personal stories or showing powerful pictures or videos to

offer opportunities for students to connect back to their own prior experiences and make connections with others and the world around them.

"We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology."

- Carl Sagan (1993)

"Nothing ever becomes real 'til it is experienced – even a proverb is no proverb to you 'til your life hast illustrated it."

- John Keats (1819)

Introduction

Focus on the STEM Pipeline

There is little doubt that undergraduate STEM education needs reform. A reported 40% of students who enter college as STEM majors actually graduate from a STEM field (President's Council of Advisers on Science and Technology (PCAST), 2012), whereas 65% of non-STEM majors graduate from a non-STEM field (Higher Education Research Institute, 2010). This undergraduate portion of the STEM pipeline is leaking for both males and females (Miller & Wai, 2015) and is particularly leaky for underrepresented minority students (Higher Education Research Institute, 2010). Some potential reasons? Students entering their undergraduate STEM coursework will likely find "uninspiring introductory courses," (PCAST, 2012, p. 1) little university support for learning difficult math (the gatekeeper for many STEM majors), and generally "an unwelcome atmosphere" from faculty. In the classroom, it is clear that active learning strategies and 'best practices' serve student learning better than more passive learning (American Association for the Advancement of Science (AAAS), 2004; Barr & Tagg, 1995; Fairweather, 2009; Kuh, 2005) and there are models for success in undergraduate STEM education (e.g. SCALE-UP; Foote, Neumeyer, Henderson, Dancy, & Beichner, 2014). However, broader acceptance of these practices in the STEM classroom has been slow. These factors jeopardize President Obama's goal to issue 1 million new STEM degrees by 2022 (The White House, 2012).

Debate will continue about whether workforce development and its economic benefits should be the driving goal of improving STEM education (Baldwin, 2009; Committee on Prospering in the Global Economy of the 21st, National Academies, & Committee on Science, 2007; Donovan, Mateos, Osborne, & Bisaccio, 2014; Palmer, Moore, Hilton, & Davis, 2010) or whether STEM development is more complex than that (Baber, 2015; Rothwell, 2013; Sipple, Miskel, Matheney, & Kearney, 1997; Stevenson & Heidi, 2014). Regardless, it is important to target recruitment and support of African American males in STEM to increase their opportunities in the job market (Palmer et al., 2010), even when the sense of urgency for diversity and inclusion dries up once the economy recovers (Baber, 2015).

It is certainly advisable to try to avoid 'the gathering storm' and keep a stable US economy and high standard of living by supporting the creation of STEM jobs that lead to new knowledge creation and discovery (Committee on Prospering in the Global Economy of the 21st et al., 2007; Donovan et al., 2014). As President Obama argues students should master STEM subjects to "help America compete for the jobs and industries of the future" (The White House, 2013, para. 2). There is ample research related to STEM attrition (Chen, 2013, 2015). But with all this focus on preparing STEM students for STEM careers, who are we neglecting and at what cost?

The Call for STEM Literacy

STEM professionals like computer scientists, engineers, mathematicians, and scientists only comprise 6% of the workforce (Landivar, 2013). By focusing efforts on STEM retention for STEM employment, aren't we neglecting the financiers, environmental lawyers, medical professionals, or politicians who will vote on STEM issues, finance STEM companies, work alongside STEM professionals, or use STEM skills on a regular basis? What of those students who wish to circumvent this momentarily well-attended path to employment and become STEM professionals themselves? We must support those students who flow outside the very narrow 'STEM pipeline' yet may one day find themselves intimately involved with STEM opportunities and challenges.

The well-being of the public cannot rely solely on the work of STEM professionals, but rather on a STEM-educated citizenry willing to engage with, challenge, and support STEM professionals. Every American student lies inside this much broader pipeline. A science literate individual, with his or her general understanding of scientific concepts and practices, can contribute as an informed and active citizen in a democratic society and "live more effectively with respect to the natural world" (DeBoer, 2000, p. 594). In his book "Why Science?", James Trefil (2008) explores why it's important for everyone to know something about science. His definition of scientific literacy is written as follows:

> Scientific Literacy is the matrix of knowledge needed to understand enough about the physical universe to deal with issues that come across our horizon, in the news or elsewhere (Trefil, 2008, p. 28).

In describing STEM literacy, Bybee (2010) expands on scientific literacy to include a working knowledge of the fields of technology, engineering, and math while developing 21st century skills of using modern tools for problem-solving and innovation. American citizens need the

STEM knowledge-base to weigh in and vote on such public issues as cloning, climate change, medical research, and future global issues unknown (Baldwin, 2009). A STEM literate public can work alongside a STEM workforce to address some of our most complex societal issues.

The importance and effectiveness of such a partnership is most clearly evidenced in the recent Flint Water Crisis (Smith, 2016). Citizens of Flint, Michigan, despite being assured the water was safe to drink (highlighted by a public display of sipping performed by the Flint Mayor Dayne Walling on local television) were concerned about the potential lead levels in their drinking water. One concerned parent sent faucet water samples to a research team at Virginia Tech who, she had read, had dealt with a similar crisis in Washington D.C. a decade prior. The team leader Dr. Marc Edwards saw the "highest levels of lead he had ever seen" (Smith, 2016, p. A12) and got to work visiting Flint and sending test kits to its residents. This example of collaboration between scientists and the public has done more than just uncover high levels of lead in the water, it has exposed a mistrust between the public and the government and a failure of science for the public good (Hiltzik, 2016). If as Dr. Edwards says "the agencies paid to protect these people weren't solving the problem… [they] were the problem," (Kolowich, 2016), investment in education for a STEM literate public is a must.

General Education Curriculum as the Vehicle for Public STEM Literacy

Fortunately, universities have both the access and expertise to foster scientifically literate students who are interested in science, able to discuss and act on issues related to science, and ready to "apply science to their own lives" (DeBoer, 2000, p. 598). As then Harvard President James B. Conant expressed after World War II, the goal of undergraduate general education STEM courses is "to start the student down a road that will ensure his arriving at some degree of scientific literacy even though he devotes his college years to the study of some nonscientific study" (Watson & Cohen, 1952, p. xiv). However, it does not appear that universities are contributing to this goal of fostering a scientifically literate population. Based on their 10-year longitudinal study, Impey, Buxner, Antonellis, Johnson, and King (2011) report that between the time before and after college, there is "no detectable improvement in undergraduate scientific literacy." It seems non-STEM major students simply cannot develop scientific literacy by taking introductory classes meant for STEM majors or by engaging in less rigorous versions of the disciplinary content with no opportunities for application (Nair, 2011), practices all too common in undergraduate general education STEM courses. These actions impede the goal of producing a STEM-literate public.

Investment in general education can help meet this need. The general education curriculum is the one "shared experience" of all students at a university (Association of American Colleges and Universities, 2002), so changes within it can reach the entire undergraduate student body. And it is an opportune time to pursue change in the general education STEM classroom, as universities nationwide are in the process of reforming their undergraduate general education curriculum. In 2009, 85% of universities nationally were at some stage of updating their undergraduate curriculum (Hart Research Associates, 2009). With an increasing call for accountability of higher education institutions (Douglass, Thomson, & Zhao, 2012), the general education curriculum is under as much scrutiny as ever before. Due to the high stakes, sweeping opportunities for change, and tradition of tension between faculty, administration, and accreditors (Del Favero & Bray, 2010), university stakeholders should navigate general education curriculum reform with great care. However, the benefits of a STEM-educated future citizenry are worth the risk.

Transformative STEM Classroom Experiences for Increased STEM Learning

According to Roth and Jornet (2014), the student ‘experience’ in the classroom deserves far greater attention by both educational researchers and the instructors themselves in both lesson design and daily student interactions. In the paper, the authors examine an episode in a high school science classroom through the lens of a Deweyan/Vygotskyan experience. During one class period, a student in the class, Jane, had invested time, money, and energy into solving a physics problem: how to make a Chinese lantern rise using a single tea-light. Jane is told by the instructor that she is to change her approach to complete the assignment more efficiently. The instructor feels she has helped the student achieve the goal of the assignment, while the student feels dejected and turned-off both to the lesson and the course for the remainder of the year. In Jane’s words, “it sucks.” If the goal of science education is to provide opportunities for students to have “transformative, aesthetic experiences” that enable students to see the world differently (Pugh & Girod, 2007) and inspire further study, then not just any experience will do. We need to identify those experiences after which students are left curious and energized, not “uninspired” (President's Council of Advisers on Science and Technology (PCAST), 2012).

It is argued that an instructor should offer opportunities for aesthetic experiences in the general education STEM classroom for this type of transformative learning to occur (Biscotte, 2015). According to Dewey (1934), an aesthetic experience is a memorable transformative transactional moment. The experience has anticipation, demanding an intensified focus by the individual. There is continuity; the moment is tied together by a unifying thread even as it ebbs and flows. And there is consummation as the moment comes to a satisfying close. These moments can occur during a game of chess, a storm, an event, or even a meal. But it’s not just any meal, it’s THAT meal. It’s the meal that is savored, remembered, celebrated for years after. The eyes close, time slows, and the mouth blows an involuntary ‘wow’ to all who can hear.

Having an aesthetic experience is much different than recognizing aesthetic qualities in an object, as one might do hurriedly touring an art gallery. Instead, the moment can best be exhibited by the artist fully immersed in creation or the observer in full connection with the art. In these aesthetic experiences there is “joy and sorrow” (Wickman, 2006, p. 148) and “surrender, receptivity, and suffering” (Wong, 2007, p. 204) that leaves the artist changed or the observer transformed.

Aesthetic experiences drive scientists in their research as well (Flannery, 1991), moving them continuously forward in the pursuit of knowledge. Nobel laureate Arthur Kornberg relates enzyme purification to ascending a mountain: the “logistics resemble assembling higher base camps”, the “protein fatalities and… contaminants resemble the adventure of unexpected storms and hardships”, and concludes with a “reward… of a commanding view from the summit” (Kornberg, 1989). Nobel laureate Barbara McClintock, based on her understanding of electropulses in plants, provides the anecdote that “every time I walk on grass, I feel sorry because I know the grass is screaming at me” (Keller, 1983). For E.O. Wilson, ‘biophilia’ or ‘love of living things’ is innate in humans (Kellert & Wilson, 1993) and should be cultivated. These scientists recognize that doing science is developing “recurrent patters of action” (Wickman, 2006, pp. 136-137), but that these habits go well beyond skills in repetition, retention, and regurgitation. Doing and learning science sound like transformative, life-changing experiences full of struggle, imagination, emotion, and growth. Learning science culminates in a new perspective on and position in the world.

To achieve this, an instructor can attend to the following six dimensions to increase the opportunities for aesthetic experiences to occur: connections, risk-taking, imagination, sensory experience, perceptivity, and active engagement (CRISPA, Uhrmacher, 2009). For an aesthetic experience to occur, the individual should have an active connection or link with the environment. This connection has emotional, intellectual, and affective components that allow deep surrender and undergoing (Wong, 2007). In an aesthetic experience the individual is confronting something new, so there is an inherent risk in bridging the gap between the known and the unknown (Dewey, 1934). And in this bridging with the world, the familiar is challenged and made new through imagination (Uhrmacher, 2009). Through engagement of the senses, the individual can go beyond seeing to perceiving the world in an intimate and holistic way (Uhrmacher, 2009). Finally, the aesthetic experience depends on an active engagement by both the mind and body (Dewey, 1934) throughout the course of the experience. As Wickman stresses, "without aesthetic experiences, science or science education – or anything for that matter – will stop" (2006, p. 148), so the instructor should attend to these dimensions to keep students moving forward, growing and transforming.

In alignment with the dimensions of aesthetic experience, science instructors can make tangible adjustments to the classroom and learning activities to offer more opportunities for these aesthetic experiences to occur (Girod, Rau, & Schepige, 2003). Students could engage in content recrafted in its own historical context to show that no fact, theory, or discovery exists in a vacuum (or lab). Perhaps students could be presented with 'what if' questions to allow for imaginative discovery: what if grass could feel pain, would it scream? How could we find out and how might we act differently with this knowledge? And rather than presenting students with a rose and asking to label its parts, the instructor could allow time for students to 're-see' (perceive) it for what it is, an angiosperm with sepals, petals, and epidermal outgrowth (NOT thorns as a popular 80's ballad would have you believe), but also what it means to that student: a symbol of a past love, the reminder of a painful fall into a flower garden, or a beautiful and functional result of generations of evolution to survive in a complex ecosystem. Offering opportunities for having aesthetic experiences is advisable, beneficial, and doable in undergraduate general education STEM classrooms, but is it happening? And if so, what impact do these experiences have on students' further engagement with science?

Impetus for the Research

In a series of focus groups held to uncover the best our general education curriculum has to offer, student responses about their STEM courses varied. Although one student described a course as 'awful' and a 'waste-of-time', another found the topics 'interesting' taught by an 'engaging' professor. One student said she liked her course so much she planned on taking another in that field. Another wanted to pick up a minor if she could 'find room in [her] schedule.' With evidence of poor teaching practices and an unsupportive classroom environment (Nair, 2011; President's Council of Advisers on Science and Technology (PCAST), 2012) paired with the fear of hurting the all-important GPA, why would a student ever pursue further STEM study if he or she didn't have to?

At a research poster session for an introductory geosciences general education course, I had the opportunity to talk with students about their experiences in the class. One student described the field trip to the local quarry where she could see, smell, and hear the environmental impact of building construction on her very own campus. A group of students described how 'stressful, but cool' it was to present their research projects to other professors, experts in the field, and their athletic coaches. Another asked me for more information on the proposed Minor in Sustainability as she wanted to continue learning about her research topic. One student even described his Thanksgiving dinner table argument with a family member regarding the sociocultural impact of the local proposed natural gas pipeline. These statements contrast the notion of uninspiring general education STEM courses featuring poor teaching practices and an unwelcome atmosphere. And they seem to map well to the dimensions of the aesthetic experience (sensory experience, risk taking, etc.) critical to transformative learning in the general education classroom (Biscotte, 2015). Thus these statements have become the impetus for more rigorous research.

Purpose Statement and Research Questions

The purpose of this study was to describe the classroom experience of STEM-philic students at Virginia Tech. 'STEM-philic students' are described here as those students who are not majoring/minoring in STEM fields, but who are attracted to further STEM study; they have the desire to take another non-required STEM course, perhaps pick up a STEM minor, or even switch to a STEM major. These students differ from 'STEM-neutral' students who may express indifference to future STEM study, 'STEM-phobic' students who have developed a fear of STEM, or even 'STEM-odiumic' students who would find future STEM study downright offensive. This last would group would include students best described as running kicking and screaming from STEM. In this context the following research question was explored: is there a relationship between students' perceptions of having aesthetic experiences in the general education STEM course and pursuing further STEM study? The subquestions include:

A. Do STEM-philic students perceive that they have had aesthetic experiences in the course and if so, have these experiences impacted their desire to pursue further STEM study?

B. In these perceived aesthetic experiences, is there presence or absence of the dimensions of aesthetic experience (CRISPA)?

Methods

Phenomenology is the study of several individuals to describe the universal essence of their conscious lived experience of a phenomenon (Creswell, 2013). The present study was designed to explore STEM-philic student perceptions of having aesthetic experiences in their general education STEM course and the potential relationship with their pursuit of further STEM study. These STEM-philic students hold the data regarding their lived experience in the classroom that I wished to describe, so a phenomenological research approach was fitting.

Data Source

The site of this study was an introductory general education geosciences course at a large mid-Atlantic top-tier research university (VA Tech). The course under study was set in a large newly renovated auditorium style lecture hall with over 500 fixed seats with pullout writing platforms, light grey carpets on the floor with grey stone lining the walls, and a large projection screen and a lectern with AV hook-up at the front. However, many of the experiences provided took place outside of this room (e.g. in a dorm room, in the woods, in the desert overseas, etc.).

At the time of the survey, 195 of the 300 students who responded were not STEM majors (or minors) and were taking the course to meet general education requirements. Over 57% of these students had declared a primary major in business related fields like Finance or Marketing, 15% in liberal arts fields such as English, History, or Philosophy, 12% in art or architecture fields such as Interior Design, and 8% were enrolled in University Studies (undecided). The remaining 8% of students were enrolled in a variety of non-STEM majors, from Public Affairs to Criminology. One of the students surveyed had recently switched her major to a STEM major (Animal and Poultry Sciences). Due to the nature of this research study, exploring transformative classroom experiences of non-STEM majors and their influence on pursuing further STEM, this participant was included in the sample. The class was made up of 76% freshmen, 17% sophomores, with juniors and seniors constituting the final 7%.

Sample Identification

In a phenomenological study, the sample represents a group of individuals "whose lives involve a revelatory relationship with the subject matter under investigation" (Wertz, 2005). The participants for this study included STEM-philic students in a large enrollment introductory general education geosciences course able to articulate their concrete lived experience. The researcher had supported the course instructor, Dr. Kinsel, in prior efforts to increase engagement and active learning in his large lecture course. Dr. Kinsel served as a valuable and supportive gatekeeper throughout the data collection process. The researcher visited the class and all 300 students in the introductory course were provided with an institutional review board-approved consent form to review and complete prior to data collection. Those who granted consent were then surveyed to find participants who met all the criteria for study: a) took the current course to fulfill general education requirements, b) did not take the current course to fulfill requirements for a major or minor, and c) articulated desires to take further STEM courses even if not required for their major, minor, or general education requirements. This survey was given with six weeks left in class to ensure students had sufficient time in the course on which to reflect and to provide enough time for follow-up interviews before they left for summer.

Based on the results of the survey, 73 students met these criteria and were invited to participate in a student focus group. Students were offered a half-point of extra credit on a prior exam to attend a focus group. Three focus group sessions, each approximately an hour in duration, were offered to accommodate as many of the 22 interested students as possible: one session included nine participants while the other two included five participants each for a total of 19 focus group participants. A short demographic questionnaire was completed by all participants to provide background information pertinent to the study (see Appendix B) including age, race, gender, year, and major(s) and minor(s).

Next, seven individuals who were able to articulate concrete memorable experiences during the focus groups were invited to participate in semi-structured interviews to dive deeper into how they made meaning of the phenomenon. Five participants responded and were interviewed, a sufficient number of participants to draw valid inferences from the research question (Boyd, 1993; Creswell, 2013; Polkinghorne, 1989). Also, through data immersion, it was determined that five was sufficient to reach saturation and redundancy in the findings (Wertz, 2005).

Participant Descriptions

The five participants, described in the chart below, included 2 young men and 3 young women. All five identified as white. The three freshman participants were 18 years old and the two sophomore participants were 19. Each participant had a different major: History, Animal and Poultry Sciences, Business, International Studies, and Economics. The student majoring in History also had a minor in Political Science. The student majoring in International Studies also had declared minors in Arabic and Middle East Studies.

Name	**Status**	**Major(s)**	**Minor(s)**	**Gender**	**Race**	**Age**
Catherine (Cat) Billings	Freshman	History	Political Science	Female	White	18

Donna Epperly	Freshman	Animal and Poultry Sciences	none	Female	White	18
Nick Wilson	Freshman	Business undecided	none	Male	White	18
Samantha Boggs	Sophomore	International Studies	1. Arabic 2. Middle East Studies	Female	White	19
Tyler Miller	Sophomore	Economics	Leadership	Male	White	19

Table 1. Description of participants

Data Collection

The purpose of holding these focus groups was to identify a small sample of related people able and willing to reflect on the concrete, lived experience of having a memorable aesthetic experience in a general education science course. In the focus groups, participants were first asked to write a short synopsis to the prompt "describe your most memorable moment in the geosciences course." This was the first step in having participants relate concrete examples of the phenomenon in a focused but open way (Wertz, 2005). Follow-up questions included "tell me more about what was happening during that memorable moment", "what other moments stand out from that course", and "what do you want to do next in STEM" (see Focus Group Protocol in Appendix A). On occasions where participants provided broad generalizations or opinions about the lived experience, the researcher would prompt concreteness, "the most outstanding quality of data sought by the phenomenological researcher" (Wertz, 2005). For example, when one participant stated "I think a lot of the pictures [the professor] showed about the mines that went wrong or poor planning on the part of other governments was interesting because it made me think," the researcher responded with "Do you recall a specific picture that resonated with you?" in an attempt to draw the participant back to a concrete component of the lived experience.

The purpose of the in-person semi-structured interview was to clarify and explore more deeply the memorable moments STEM-philic students recounted during the focus groups. These interviews lasted from 30 to 50 minutes. During the interview (see sample interview protocol in appendix C), open-ended questions of the participant included:

1. Describe your most memorable experiences from this Geosciences course.
2. What are your plans for continuing STEM study?
3. What impact (if any) did these memorable experiences have on your desire to take another course in STEM?

Explication of the Data

To prepare the data for analysis, all focus group and interview recordings were transcribed. These data were analyzed following a procedure outlined by Creswell (2013) which builds on Moustakas' (1994) description of the Stevick-Colaizzi-Keen method. With data collection and author's bracketing complete, a list of unique 'significant statements' or 'meaning units' (Wertz, 2005) were pulled from the source data and grouped into 'meaning clusters' or themes. Next, a 'textural description' was produced to portray what the participants experienced in their own words followed by a 'structural description' to describe the context and setting of the phenomenon (Creswell, 2013). The former featured direct quotes validated by the participants. The latter highlighted the structure of the class and classroom and those descriptive statistics significant to the setting of the phenomenon being explored (e.g. list of majors represented in the class). These descriptions were then combined into a unified text describing the 'essence' of the participants' experience of the phenomenon.

In the first stages of analysis, an emergent coding and clustering mechanism was used. The final stage of analysis was driven by an aesthetic experience framework and its dimensions as outlined by Uhrmacher (2009): creativity, risk-taking, imagination, sensory experience, perceptivity, and active engagement (CRISPA). The shared experience was analyzed at this stage to uncover the perceived presence or absence of an experience and its potential relationship with the phenomenon of STEM-philia. A matrix was constructed with the six components of aesthetic experience cross-matched to the significant statements culled from earlier stage data analysis.

Trustworthiness

The researcher used multiple methods to elevate trustworthiness including member checking, external review and validation, and bracketing. As a means of member checking, the researcher utilized interview questions to both confirm the significance of statements made during the focus groups while also opening the lines of further clarification and exploration. In addition, the researcher provided each participant with a copy of their interview transcript. This allowed participants the opportunity to correct statements and expand on topics of discussion.

To increase trustworthiness of the data analysis process, an external interpretive review team with expertise in phenomenological research was commissioned. The researcher participated in a live reading and discussion by the team of one focus group and one interview transcript offered by the researcher. This team provided validation of the appropriateness of the focus group and interview questioning as well as modeled effective phenomenological emergent coding and clustering processes. In addition, as a means of enhancing validity and adequacy of the aesthetic experience matrix, a review was conducted by an external scholar with expertise in the development of, and research related to, the six components (CRISPA) of aesthetic experience.

The phenomenological researcher is not without bias or personal experience (Hammersley, 2000). Therefore, before exploring the lived experiences of STEM-philic students, the researcher attempted to 'bracket' out his own experience as a way of setting it aside and taking "a fresh perspective at the phenomenon under examination" (Moustakas, 1994). The researcher acknowledged his background as a biology major, science teacher, and current administrator working with general education while recalling his own most memorable moments in the undergraduate STEM classroom. In addition, memos were produced throughout the process to allow the researcher to continuously try to aside personal experience and perspective to allow for a more open review of the data.

The Lived Experience

Student participants throughout the process were willing to discuss what they remember from the course. During the focus groups, students were open, both with each other and the researcher, to providing opinions, reflections, and perspectives on their most memorable moments from the course. Following the focus groups, five of the students who were able to articulate actual moments related to the course, rather than just general perceptions or opinions, participated in follow-up individual interviews to provide a deeper exploration of their most memorable moments. In this first stage of data analysis, the researcher grouped 'meaning clusters' together to uncover the shared lived experience of the STEM-philic student in an introductory general education science course. Four themes emerged: a) *having a conversation,* b) *making connections*, c) *planting seeds*, and d) *identifying authority*.

The meaning clusters that support the theme *having a conversation* were a) enter the conversation and b) elevate the conversation. The meaning clusters that support *making connections* were a) making a connection to personal experience, b) making a connection to prior experiences, c) making a connection to other coursework, and d) making a connection to family, friends, or loved ones. The meaning clusters that support *planting seeds* were a) seeds of inspiration, and b) eye opening. The meaning clusters that support *identifying authority* were a) authority of data, b) authority of the professor, and c) authority of the classroom.

The students recounted and expanded on a variety of memorable experiences from the course. Some of these experiences came from inside the walls of the classroom, e.g. watching a particular video clip, recalling a professor's story, or discussing a topic with a peer. Other experiences came from outside the classroom but happened over the course of the semester, e.g. discussing a class topic with a friend or family member, reading an article assigned from another course in a dorm room, or watching a video as homework for the course. Still other experiences occurred outside the timeline and location of the course completely, e.g. an event from a study abroad experience during the summer prior to the course, a memory from a family trip as a child, or a conversation with a friend overseas years prior to the course. The last group of memories had such a powerful impact on how the participants made meaning of their course experience, particularly in connecting course topics or events back to these prior experiences, that they were treated as memorable experiences from the course by both the participants and the researcher.

Having a conversation

Each of the participants recounted a conversation or discussion among their most memorable moments from the course. Students found these conversations important to applying, expanding on, and growing from the knowledge gleaned from the course.

Entering the conversation. Some participants revealed that the knowledge, confidence, and skills developed through the course allowed them to enter a conversation they would have otherwise been unable or unwilling to enter. For example, Cat Billings recounted how growing up she participated in many family discussions of current events around the dinner table, usually related to topics she brought up from school, something that had "always been important to her family in general." Cat would initiate the conversations but then feel left on the sidelines to listen. However, over the course of this class, her role shifted. She stated,

> Over Easter break, I was visiting my grandparents. They are professors here in biology and forestry so they're very involved with the school. My aunts and uncles were there and there was a big family discussion about water quality. So using the Flint Water Crisis example from class, I could talk to them and share things they may not have known when they pretty much know a lot of things happening at the school and in science. Because in the past I couldn't keep up or add anything. I just felt like I could add to the discussion instead of just taking away things from my grandparents. So saying something to them was pretty cool instead of just hearing it.

Contributing to the conversation allowed her to fit in at home as she was able to "add to the discussion instead of just taking away things."

Similarly, Donna Epperly was able to enter a conversation with her boyfriend based on work he was doing for another class. Her boyfriend was looking for help on his English homework ("because he's terrible at English so I help him"), annotating a New York Times editorial about lead poisoning. He mentioned that the Flint Water Crisis came up in class and asked if she had learned about it in geology to which she replied, "Yeah, we did actually. The professor went over it for a good day or two and keeps bringing it back up because it's relevant to everything and how it all leads back in some weird circle." Her response reveals both excitement to contribute to the conversation and recognition of the interconnectedness of people and the earth. After she read the article, Donna and her boyfriend had a lengthy discussion in her dorm room about the impact of the issue on children. This went well beyond the initial goal of helping with article annotation. She stated,

> We talked about how [the people featured in the article] were so interested… dedicated… to helping children and families as it was having a big impact on small children to have toxins and lead poisoning which is happening in the Flint Water Crisis, which causes a lot of development problems for children. It was interesting to see how someone you wouldn't expect ended up relating back to it.

According to Donna, this conversation might not have happened had she not spent a great deal of class watching videos, reading articles, and hearing lectures related to the current event. In addition, Donna was surprised by the fact she could discuss information from the course with her boyfriend. This element of surprise in being able to take course information out into the real world was common to each of the participants.

Elevating the conversation. Participants were not only able to enter the conversation, but also able to contribute to a discussion in a more informed way. According to the participants, it was important that the professor offered these opportunities to try out their new found knowledge and opinions, repeatedly and in a safe and supportive environment, so they could go beyond mere entry into the discussion. Donna stated,

> The person I sit next to, we just talked every day. It was really nice to actually know someone. It made it a lot more comfortable experience. And when you know something,

> you can explain it to them. Because that's what the girl who sat next to me did a lot. We would talk when [the professor] would say 'have a discussion about oil impacts on various countries' and then we would talk and compare China to the US.

Some students reported frustration when they were asked to discuss a topic but their classmates hadn't read the article or watched the video. However, armed with knowledge and confidence attained in the classroom, participants had, as Cat described them, "more intellectual conversations" outside of the classroom as well. Nick Wilson described a two-week long conversation with a high school friend over text:

> So we got on the subject of NASA and climate randomly. It turns out he, well, I don't know if he denies climate change but he thinks if it is happening humans have nothing to do with it and it's not a big deal. So before this class there is no way I could have had a productive conversation about it, a respectful one where we both make our points. I mean it's not like I couldn't have been able to contribute, but my views wouldn't have been as sophisticated as they are now. My points wouldn't have been as educated. It's kind of hard to drive that point home without all the facts. We were able to have a pretty lengthy and reasonable conversation.

Nick recognized that although he may have had a similar conversation at some point, it may not have been as 'productive' and he would not have been able to contribute the high level of 'sophistication' to the conversation and the conversation may have ended prematurely.

Making Connections

The second theme to emerge was *making connections*. Participants reported that making connections to themselves (interests and experiences), other people, and other coursework was an important and valued part of the classroom experience, particularly as non-science majors. Samantha claimed these connections brought the course content “close to home.” Sparks or prompts for these connections included videos, articles, personal stories, pictures, lectures, or conversations, often on the topic of current events. Cat recalled,

> The current events were really important for me. Like using the Ted Talk to discuss the bigger issues of the current population growth. The Flint Michigan case. The various catastrophes like the Colorado River thing. I think including those in this broad course because you might see it in the news and come up again and that reinforces what you’ve learned.

Making a connection to personal interest. Some participants made a connection between a topic in the course and their own personal interests. Nick said “I love numbers and statistics” and that “anytime [Dr. Kinsel] would put up a graph, I would think ‘that’s cool.’” Tyler described himself as a “huge outdoor enthusiast” who connected to seeing the pictures of the Colorado River pollution and glacier melting. Donna admitted, “I just really love science” and “I hope to work with kids” and found the readings and videos about the lead water problem in Flint interesting as it “had such a big impact on children and how it could cause a lot of damage at such a young age.” Samantha recalled,

> We watched a video pretty early on. It was a homework video about the implications of oil in WWII which was so interesting to me. Because I also love history. I’m sure a lot of my friends in Poli Sci and Int Studies could say the same thing but that was super interesting because I had never even thought about the environmental aspects of WWII. That was never on my radar until watching that. I was actually doing something else and

> I just had it playing in the background and I remember sitting down and watching and thinking 'wow this is interesting.'

Samantha, a member of the Corps of Cadets and an International Studies major found multiple interests stoked by one video. This allowed for a full engagement with the video that may not have occurred otherwise.

Making a connection to prior experience. Each participant described a moment when something in the course sparked a clear connection to an experience they have had with the world around them. When hearing the lecture about coal in class, Donna recalled her childhood family drives through West Virginia and seeing the long coal conveyer belts, the large mine with people working it, and the small coal towns close by. She stated, "the class gave me respect for how that mine works and how those people put their lives on the line for it." For some participants, this connection of course content to personal experience had a fundamental impact on the way they see the world now. For example, Tyler Miller recounted the summer in high school he spent on a ranch in Alberta, Canada that resides next to melting glaciers. He recalled,

> And there were actually pictures that Dr. Kinsel had shown of Glacier National Park that was just south of me. It hit me while I was there but then seeing pictures of very similar areas in similar parts of the world, um, it was just astounding that within my lifetime so much could have changed largely because of what we're doing or not doing.

Tyler claimed he recognized the impact of climate change both in the moment and when looking at pictures from that same area. This allowed continued reflection on an experience, an important action to keep learning intact. Samantha spent a summer in Jordan as part of the Project GO study abroad program offered through the ROTC. She stated,

> Water was a huge huge culture shock there because our host dad would say 'hey you guys can't shower until Friday' and it's Tuesday and we're thinking 'oh crap.' We're used to showering every single day. Then some mornings we wake up and there's no water to drink. There's no water in the water tub. There's no water in the faucets. Then you would hear the water truck come on Friday and everyone screams 'yay, it's a water day.' Because in class, we were talking about how water could be the cause of the next global war and how water is really the upcoming thing we need to be working on. We need to be studying it because it's going to cause a lot of conflict. I'm sitting there thinking 'I bet these people don't even know what it's like to not have water.'

Samantha had a powerful realization that taking showers, an everyday occurrence here in America, is a luxury in some parts of the world. She recognized how this experience allowed her to make sense of the potential for a global war over water. Each participant connected to prior experiences to make meaning of the course content. Tyler stated that those experiences allowed him to "put [the content] in context" making it "feel much more personal." Samantha stated,

> It was a lot easier to see the climate change and global warming when you're in a developing country than it is when you're here. It wouldn't have hit quite so close to home. I wouldn't have understood it. I have friends in Jordan and they say 'Jordan is the second water-poorest country in the world' but you don't really understand the implications of that until you put it into context.

Because of her experience, Samantha was able to put into context an isolated statistic about the impact of global warming for water scarcity in Jordan. She was able to bring it "close to home" to truly "understand the implications" of the statistic.

Making a connection to family, friends, or loved ones. As cited in the discussion of the prior theme, each participant relayed conversations initiated or framed by course content. In some cases, these conversations served as a way to connect to someone else: Cat to her grandparents, Donna to her boyfriend and classmate, and Nick to his high school friend. In addition, Cat stated "[Dr. Kinsel] talked about how more rural people might be affected if they have wells. My family has a little farm and a well, so at home it made me think of that as in I want my family to have clean water and be safe." She also stated that "I could relate [the discussion about pollution in the Colorado River] to my grandfather and the work he's doing because he is one of those people trying to help out in Chile." Donna recalled, "I have a sibling with autism and down's syndrome so to go through that and know that [lead poisoning] could also be a cause of it is something that's important to me."

Making a connection to other courses or major. As non-science majors, participants were excited (and in some cases surprised) to make connections to other courses or their major in general. Nick, a business major, recounted the time when a finance professor brought up fracking, "I was 'hey, that's what I actually did my project on, my poster session on fracking, so I know all about this.'" Tyler, an Economics major, remembered seeing the same graph on CO2 production in both geosciences and economics course. Tyler stated that it was important "being able to talk about basically an economic topic in a geology class because then I can see that it really does all tie in." Also, Tyler reported that watching a TedTalk on population growth was memorable because "the population issue is something that is very relevant to me… as an Economics major." And Samantha stated,

> My [Middle Eastern Studies instructor] said 'but yet there are countries like Jordan living this way and yet people still don't accept the idea of global warming. Still don't accept

> the idea of water scarcity.' So that's what made me actually remember the geosciences course about how yeah we're taking measures to reduce water scarcity.

Without these connections, students would have failed to see the relevance or context of broad concepts like global warming or population growth.

Planting Seeds

The third theme that emerged was *planting seeds*.

Eye opening. Participants recalled eye-opening moments, moments when they saw their world differently. Tyler stated, "In class, I saw pictures of China, Indonesia with the ocean streams taking all of the trash and it's just covered and it's horrible and that's a really severe problem." Cat followed that "seeing those things and then hearing him talk about how important they are sort of opened my eyes to what's actually going on." Donna echoed, "this class definitely led me to start thinking about the environment and how we need to really think about how we care about the environment." Tyler stated,

> That particular [TedTalk video] about the population stood out to me because that's an issue that [Dr. Kinsel] said 'we can affect it', 'we can actually stop population growth' which is crazy to think about. That was a surprise to me.

Once enlightened to the impact of the issue, students saw the issues differently. As Samantha provided, "I think it just makes it a little more personal when you consider, yes something polluted a water system, but when you think about the people who were affected by this water system, that's what I tend to think about more often now."

Seeds of inspiration. Participants related that some moments from this course may have had an impact on their future. Some participants stated they felt a call to action. Donna reported, "We had the lecture and video on population growth and I would like to go help third world countries to hopefully get it to the point where they are developing." Tyler stated that this course reaffirmed prior commitments to the environment and finding a way to help. He stated, "I'm an economics major looking to get in the field of service so that I can hopefully overcome the government failing us, like with the climate summit."

When reflecting on what they would like to do next as a student of science, Cat reported, "I'd be interested in doing something big like that [Flint Water Study]. That was an interesting discussion about finding those opportunities to be involved in something more meaningful than just classwork." Samantha stated, "I would definitely take a class on water that covers water distribution and water resources in the future. That's something we talk about every single day in International Studies." As aforementioned, this is also a key connection to another course.

Some participants even reconsidered career aspirations. Nick responded, "lately I've been thinking economics would be good for me since I am interested in politics and that gets me excited and you can obviously super apply it there. And since this class, I'd focus on natural resources." Cat recalled,

> Political Science-wise, I originally wanted to go to law school and deal with estate planning and writing wills and stuff but then after this course I know the professor talked a lot about environmental law and how that's a big deal. So now I'm sort of thinking about the environmental law and looking into that because a lot of people in my family are involved in biology and different environmental things.

Identifying Authority

The final theme to emerge from the data was *identifying authority*.

Authority of data. Students cited the importance and value of data in making scientific claims. As Donna put it, "If we're talking about scientifically, then it's really important that you have the information or data or statistics to prove that yes, the ozone is going away." For some participants, data in the form of graphs or charts carried authority. Donna stated, "it's easy to picture the graphs and data showing the change." Tyler stated, "any visuals and graphs stuck with me and made me see that this was important." Samantha agreed, "we saw graphs of the actual receding shorelines and that was a pretty big change and then the predicted graphs about what the shoreline might look like, especially in Antarctica. I thought 'wow, that's real, that really happened' You could look at it right now and see that."

Some participants recognized how important it was for the professor to provide this type of data to help guide student opinions. Tyler recounted an example from Dr. Kinsel's climate change lecture, "he literally shows you government factsheets and charts and says 'I'm not telling you to make your decision, here are the facts. Here are facts against it, here are facts for it.' And they're pretty overwhelming for it."

However, some participants identified a more nuanced view of data and its value. Nick explained, "the data [Dr. Kinsel] showed in class was good… I think data is a very tricky thing. It's not like you should just take that data and say "yeah, this is the answer" but it provides a good source." Donna came to the realization that an argument is just opinion without scientific support, something she felt other people do all too often,

> It's like many people, there are plenty of videos of people who disagree with global warming and they start with 'I'm not a scientist, but' so most of their facts [makes air quotes gesture] are just opinions. It's not really a fact, it's what they believe and what they think. But when you take in all the facts and the data for years showing how the world is slowly growing in temperature it's easy to be 'yeah, there's global warming going on.'

Authority of the professor. Students granted authority to the professor based on his prior experiences and expertise. It was important that Dr. Kinsel brought personal experiences from the field, from the "real-world", rather than just accurate information. Nick stated, "subject matter like this that is the least bit controversial and you know the person presenting that material is involved in this stuff and you know he's doing things about it. It's his job." Tyler agreed, "he's been so many places, put years and years into his knowledge. Getting to have a professor who is definitely an expert in this field is really important and we are really fortunate." Nick expanded, "just the fact that he's so involved with it gives you more confidence in what he's saying. Just because he's lived it and you haven't. As opposed to someone who just… you know research stuff online." Samantha appreciated that the instructor could bring personal stories to the course, "I think he talked about how he worked for a gold mine and then he talked about once how there was a break and it ended up polluting the water system around where he was working."

Students valued the instructor's personal experience as a highly important tool to engage them in class, but also elevated the validity of the course material knowing he has had those experiences and has "lived it."

Authority of the classroom. In multiple cases, students gave authority to all information taken from this course. In reflecting on a time when she entered a conversation with her roommates about climate change, Cat stated, "I was informed and I knew it was right because it came from the classroom not just from something my friend said or something I read on the internet." Samantha recounted her thoughts during a discussion about climate change in her Middle East Studies class, "I thought back to the [geosciences] class and I thought a lot of people could benefit from actually knowing the facts instead of blanket statements." The students perceived they had access to the 'truth' about global issues and wished others did too.

In summary, upon explication of the data through an emergent open coding process, meaning units based on significant statements were clustered to form the four themes previously discussed: *having a conversation*, *making connections*, *planting seeds*, and *identifying authority*. In the next section, significant statements culled from the data were analyzed using the CRISPA framework, a lens for analyzing the presence or absence of aesthetic experiences.

Searching for Aesthetic Experience

During the last round of coding, all of the memorable events described by the students were evaluated for the presence of the components of an aesthetic experience: connection, risk-taking, imagination, sensory experience, perception, and active engagement (CRISPA). According to Uhrmacher (2009), it is debatable as to how many components must be present to elevate any experience to an experience, but he suggests certain components should be present to allow for an aesthetic experience to occur, including connections, active engagement, and sensory experience. In other words, without these, it would be hard to initiate and sustain an experience. This suggestion is not based on empirical data, but it is a logical inference that if each of these are present, an active physical/mental/emotional transaction between the person and an object in his or her world can occur. The remaining three components, perceptivity, risk-taking, and imagination may not be absolutely necessary or exist in some predefined combination, but are deemed vital to allowing an aesthetic experience to reach fruition. Some of the components overlap by nature, thus there should not be considered hard fast breaks between the components.

Students shared many stories that mapped to one or two of the components. For example, when recounting her memory of watching the TedTalk video on population growth, Donna stated, "it was one of my favorite Ted Talks because there's this cute little old man explaining things with boxes and pulls a little plane out or a bike. It's really entertaining to see how this is their population growth." It is evident that Donna made a connection to the video as an object of her environment. There is also evidence of sensory experience as she watched and listened to the video. However, even though Donna describes the video as 'one of her favorites,' there is no evidence of active engagement in that her mind and body were in full attendance to the object, but rather passively watching and 'enjoying' the show. She reported that she had seen this video before, so there was no evidence of risk-taking. It is missing perceptivity and imagination, as her description does not go beyond mere recognition and description of the video. This is not to say Donna didn't actually have an aesthetic experience (or that those components were not present) while watching this video. But without further probing on this topic, there is insufficient evidence from the data to conclude that all the necessary conditions were met for the student to have an aesthetic experience.

Few of the shared memories mapped to the required three components (connections, active engagement, sensory experience) and only two mapped to all six components. One particular in-class memory which contained evidence of each of the six components of an aesthetic experience is unpacked below. This section includes a vignette with long first person accounts of this memorable experience followed by the teasing out of each component of an aesthetic experience (CRISPA). Descriptions are pulled from other experiences as needed to round out the shared nature of each component across participants.

Vignette

As a requirement of the course, each student worked in a group to complete a research project exploring a different type of natural resource (e.g. wind energy, coal, or natural gas fracking). The students created an informational poster about their topics and then presented these posters at an end-of-course poster session held in a large ballroom on campus. Samantha recalled a moment from that poster session when she went to evaluate a peer's project (also required of the course),

> I actually know the person who did the presentation, so I walked up there expecting him to say 'hey just give me an A on this project' and I would just check the 10 on the sheet but no, he explained how his grandfather was a moonshiner and his dad as a kid did it. He said 'I knew this process already and it wasn't until I actually studied the process of making corn ethanol that I understood how the two related to each other.' And he first of all, went through the entire process of making moonshine so I'm sure if I wanted to I could probably do it now because he was so in depth, so detailed. How you refine it and refine it and the alcohol content gets lower. If you stop at that point, you get the fuel. But without the refining and added sugar and all the extra steps, you are basically making corn ethanol. And I thought 'that's gross' because it's kind of like you're drinking fuel, just further refined fuel. And I was so intrigued I didn't want to walk away. We got called over to [take attendance] but I thought that was really cool and a lot more relatable than just getting facts told at you. I was actually intrigued by it and captivated by it. I got a lot more information out of that than I did out of any other session.

Connections

Samantha had a personal connection with a peer and his poster project. It was an intellectual connection as Samantha left with a great deal of content knowledge about the topic, but it was also communicative as Samantha was able to share the presenter's personal experiences through his vivid stories about his family of moonshiners and the moonshine distilling process.

As described in a prior section, participants made a number of connections with other people. For example, Cat connected with her family over dinner and Nick connected with an old friend over text. Participants made connections with pictures, videos, graphs, stories, and texts. Samantha made a powerful connection between her experience in Jordan, where showers were rare and bottled water was nonexistent, with class discussions about water scarcity. According to Samantha, the phrase 'water scarcity' carries little meaning as "you really don't understand what it's like to be so thirsty." This harkens back to Keats' quote to open this article: "Nothing ever becomes real 'til it is experienced – even a proverb is no proverb to you 'til your life has illustrated it." Without the life experience, how could someone make 'real' sense of a statistic about another country's global ranking in water scarcity.

Risk Taking

Samantha engaged in risk-taking when she participated in the peer evaluation portion of the poster session. Samantha stated, "I walked up there expecting him to say 'hey just give me an A on this project' and I would just check the 10 on the sheet but no, he explained how his grandfather was a moonshiner and his dad as a kid did it." This challenged her expectation that she and her classmates would do nothing more than fulfill the requirements of the course. She was instead thrust into a personal exchange.

Given the opportunity, students sought out and took risks, usually in the form of conversations or life experiences. Nick described risk-taking when he had a discussion with his friend, “we disagree on a lot of stuff but we like talking about those political issues. I wanted to know coming from his super-conservative mind, what were his thoughts about [climate change]” when it might have been more comfortable to avoid these controversial topics. Samantha took a great deal of risk to enter the desert with a fever and little access to water, a life experience on which she could reflect and ground her understanding of content throughout the course.

Imagination

In making sense of her understanding of the relationship between ethanol and moonshine production, Samantha stated, “it’s kind of like you’re drinking fuel.” Using her imagination, she was picturing the act of drinking fuel to relate the two similar production methods. Samantha could have listened to these descriptions and mechanically filed them away, but instead she internalized and personalized the explanations into a powerful metaphor to make sense of the story.

Donna had an imaginative reaction to reading the lead poisoning article when she stated, “I thought to myself, ‘Oh my God, I’m gonna die.’” This use of imagination elevated the stakes and implications of the article to a dangerous pitch. In discussing her trip to the desert, Samantha stated, “I remember thinking ‘this heat and desert was what life was like hundreds of years before me,’” a clear use of imagination in the middle of an aesthetic experience.

Sensory Experience

There is evidence of sensory experience when Samantha connected the production of corn ethanol with that of moonshine, "I thought 'that's gross.'" Even without tasting it, she had a physical, sensorial reaction to learning of the similarities between fuel and beverage production.

Donna had a sensory experience visiting her grandfather in China. She stated, "when we were there, it was definitely a lot harder to breathe… but you would raise above the cloud level and were just in clouds. It was really refreshing and cool and pretty." In her trip to the desert, Samantha engaged every sense,

> I was just dying. I had a fever because I was sick too at the height of my fever and there was so much dust in the air. Around me were children riding donkeys, tourists taking photographs, and camels laying covered in flies. The sun was so hot it seemed to be ringing in my head. I felt so depleted and drained, and it wasn't for a few days that I started to feel well again.

Tyler saw beauty, but also made meaning of climate change through a firsthand sensory experience,

> On this trip I went up north in Alberta to this place called Lake Louise in the Seven Glaciers Area. There's a big tree house, a beautiful hiking route, and I spent the night up there in a tent. The Seven Glaciers were, like, kind of pathetic. There were several points throughout the night when I was woken up by avalanches from the glaciers melting. Literally over the course of 8 hours of sleep I was probably woken up 4 or 5 times from different avalanches.

Perceptivity

Samantha engaged in perceptivity when she visited her peer's poster presentation. She stated, "I was intrigued by it and captivated by it" and "I couldn't walk away," implying that she was engaged long enough to go beyond merely recognizing the object to 'resee'-ing the topic of moonshine and ethanol in a new light. She also stated, "I'm sure if I wanted to I could probably do it now because he was so in depth, so detailed. How you refine it and refine it and the alcohol content gets lower." She left with a much deeper understanding of both moonshine and ethanol. She may not see the world differently, but she saw moonshine as more than just a drink, but as a process… and a "gross" drink.

There is evidence of perceptivity in Cat's description of staring at her well and wondering if her family and community could be impacted by the pipeline, if they would "have clean water and be safe." She re-saw beyond the well as a conduit for water, but as a potential danger or hazard to her family and well-being.

Active Engagement

Samantha provided evidence of active engagement as she was both mentally interested and eager in hearing more about the topic and physically invested in standing in front of him rather than walking away or tuning him out (both choices she had and did not take). Tyler reported, "I saw a video last night of a sea turtle with a plastic straw jammed in it's nose. It was heartbreaking. I started to respond to some of the misinformed comments, but I deleted it!" This implies that Tyler was both mentally and physically engaged with the video interface. Nick demonstrated an active engagement with his phone in his conversation with a friend by continuing the discussion over text over an extended period of time.

Discussion

The purpose of this research was to explore the shared lived experience of STEM-philic students in an introductory geosciences course, particularly as it may or may not relate to having an aesthetic experience. The participants shared a variety of memorable moments related to the course that allowed the essence of this lived experience to emerge. To explore the implications of that lived experience, an overall research question was considered: is there a relationship between students' perceptions of having aesthetic experiences in a general education STEM course and pursuing further STEM study?

Dewey (1934) stated that an aesthetic experience isn't just any moment, it is that moment (e.g. that storm or that meal). Therefore, when students recalled concrete lived experiences from the course, they were separating the memorable from the 'humdrum.' The mere fact that the shared moments were memorable implied that students underwent an aesthetic experience to some degree, but to better draw conclusions to this question, the sub-questions were explored.

First, do STEM-philic students perceive that they have had aesthetic experiences in the course and if so, have these experiences impacted their desire to pursue further STEM study? Some students provided a memorable experience that clearly linked to their desire for further study. Samantha underwent a powerful experience in the desert while studying abroad, a moment in which she swore she would "never take water for granted again." This had a direct relationship with her desire to take a course on water. This desire also aligned with her academic major pursuits and was confirmed by the instructor. As she put it,

> I would definitely take a class on water. Maybe water distribution and water resources in the future. That's something super important that we talk about every single day in International Studies. Dr. Kinsel says all the time that if you're gonna study anything, study water. It's definitely going to be on the forefront of the news.

Tyler professed the desire to take follow-up science courses that "dive deeper" into the issues of resource geology as they would tie directly to his economics major and his personal interests of being "a huge outdoor enthusiast." These desires aligned with the stories he shared about spending a summer at a camp with direct evidence of climate change and reacting to pictures of mine leaks in "beautiful pristine rivers." Cat shared her desire to switch from estate planning to environmental law. This desire aligned with her powerful experience talking to her family about the political nature of fracking and considering its implications on her home and community. Nick recognized that the more he wished to engage in political discussions or action, the more he would need to research political issues like natural resources and climate change. And Donna even switched her major to Animal and Poultry Sciences to participate in the interrelationship between people, animals, and the world around them, "I can deal with learning about animals and how they correspond to people and how they impact the world." This goal aligns with her discussions with her boyfriend and her friend overseas in which, based on her newfound knowledge for the interconnectedness of science and society, she feels a great responsibility to serve others less fortunate.

From the results, it cannot be concluded that any one given moment caused students' future desire to pursue further STEM study. However, there was clear alignment between the experience and the desired pursuits. The course stoked students' prior interests, allowed for connections to prior experiences, supported students in taking the content beyond the walls of the classroom, and helped guide students to further pursuits in STEM broadly. Students had opportunities to fine-tune their understanding of the material in a safe environment leading to a more nuanced understanding of scientific data and its implications on society. These students then took their newfound knowledge and perspectives to enter and elevate conversations with family, friends, and roommates beyond the walls of the classroom. This willingness of students to engage and grapple with science issues strongly aligns with the definition of science literacy proposed in the introduction (Trefil, 2008). Therefore, there was a relationship between students' perceived aesthetic experiences and their desire to pursue further STEM study.

Next, in these perceived aesthetic experiences, was there presence or absence of the dimensions of aesthetic experience (CRISPA)? Each memorable moment listed above was mapped to the six dimensions of aesthetic experience: connections, risk-taking, imagination, sensory experience, perceptivity, and active engagement (CRISPA). Several experiences met all or nearly all of the components of an aesthetic experience, including Samantha's trip to the desert, Tyler's night in Seven Glaciers Area, Samantha's interaction with a peer's poster project, and Cat's discussion at the family dinner. The others listed mapped to at least the minimal three components (connections, sensory experience, active engagement), the threshold for allowing an aesthetic experience to occur. Therefore, it can be concluded that in the perceived aesthetic experiences that aligned with their desires for further STEM study, the dimensions of aesthetic experience (CRISPA) were sufficiently (or even completely) present.

In summary, students made strong connections between the course content and their prior experiences, personal interests, family, friends, and classmates, and other courses and major. Participants developed a more nuanced view of science, data, and the implications of science on humanity. Seeds were planted for further inquiry and further study. Students took the issues, content, and experiences to conversations with friends, family, or classmates. Students had aesthetic experiences, either prior to or within the space and time of the course, powerful experiences on which they were able to ground course content. And these student experiences aligned with their desires to pursue further STEM study.

Limitations

One focus group was cut short for multiple students to make it in time to another course. It is not known whether students who had not articulated concrete memorable experiences to that point (thus excluding them from recruitment for follow-up interviews) would have shared that had the focus group run longer. It cannot be known with certainty whether new themes would have emerged from this expanded sample.

Additionally, it was cited by the external phenomenological review team that during the focus groups and interviews the researcher talked too much in some instances. Although this occasional use of humor and personal anecdotes helped in some cases to build rapport with the participants, in other instances the researcher may have led the participants to statements he wanted to hear rather than limiting the discussion to the participants' perceptions of how they made meaning of their course experience.

Implications

Creating classroom opportunities for students to connect prior STEM knowledge to current content is a well-documented practice. D. P. Ausubel (1968) famously stated, "the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly." However, based on the results of this study, instead of just finding out what they know, an instructor should create opportunities for students to connect to what they have *experienced* to foster long-term interest in growth in STEM. Classroom 'sparks' for students to make these connections included videos, articles, lectures, graphs/charts, in-class discussions, out-of-class discussions, and the group poster project. Students specifically cited pictures, videos and media that provided a real-world context for the content (e.g. Ted Talks, news articles, pictures of environmental impacts, etc.) For some participants these sparks led to 'eye-opening' realizations of the implications of resource geology on humanity. But it was important that students had a variety of objects onto which they could direct their attention as some were not always readily engaged in the large lecture course. As Nick put it, "that class is probably the second biggest class I don't have to pay attention in." However, by offering opportunities for connections to prior experiences through a variety of means, an instructor can leverage the power of aesthetic experiences in students even if they didn't occur in the course, a particularly challenging endeavor in a large lecture auditorium setting.

In addition, these non-STEM major students valued opportunities to go beyond the dry, rote process to the human impact of science. It is in the study of the intersection of science and humanity that these students came to a true understanding of science. As Samantha stated,

> for me, not being a science major, not necessarily being a math mind, but context I'd say is extremely important because the process for me is a little irrelevant if you don't understand what implications that has… because that way I could understand in action what we were talking about.

Future Research

This study explored students with 'desires' for future STEM study, however a longitudinal study that follows students beyond their desires to actual pursuit of courses along their college career would be fruitful. Also, an exploration of the lived experience of the STEM-phobic student (non-STEM major taking STEM course for general education but NO desire for further STEM study) would provide contrasting perspectives to paint a larger picture of the lived experiences of all students in a general education STEM course. In addition, the question remains whether this essence of the lived experience extends to students in a variety of STEM courses under a variety of instructors.

Those participants fortunate enough to have traveled the world (study abroad, family trips, summer camp, etc.) seemed to have had a great deal of experience on which to ground the course content. Further research is needed to see if those students without travel opportunities prior to the course are as readily able to see the relevance and real-world implications of the course content. This will also speak to who has access to these opportunities for having aesthetic experiences and who does not.

Some questions that arose during the data explication process include: are certain components of having an aesthetic experience required? Is there are a varying degree of intensity of aesthetic experiences? And are there certain pedagogies or classroom environments that consistently enhance opportunities for students to have aesthetic experiences? Further empirical research regarding the CRISPA framework is needed.

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Appendix A. Focus Group Protocol

Facilitator Name: ____________________

Date of Focus Group: _________

Participant Code(s): ____

Demographic Questionnaire given to participant (found in supporting documents).

Activity:

Students will write a short response to the following prompt: describe your most memorable moment in the geosciences course.

Sample Follow-Up Questions:

1. Please describe further what was happening during this most memorable moment.

2. What other moments stand out from that course?

3. What do you want to do next in STEM?

Appendix B: Demographic Questionnaire

The participant will complete the following brief questionnaire to provide us with pertinent background information.

1) Age? _______________

2) Gender? _________________

3) Race? ___________________

4) Current status? (Circle One) Freshman, Sophomore, Junior, Senior

5) Major(s)? ____

6) Minor(s)? ____

If all the information you provided above is accurate, please sign your name and date in the spaces below.

Participant name (print): _______________________

Participant signature: _______________________

Date: ___________

Appendix C. Sample Interview Protocol

Interviewer Name: ____________________

Date of Interview: _________

Participant Code: ________

Questions:

1. Tell me about your geosciences course.

2. Describe your most memorable experience(s) from this geoscience course.

a. When you look back on this moment, what do you see?

b. What were you doing during this experience?

c. What was happening around you?

3. What are your plans for continuing STEM study?

4. What impact (if any) has this course had on your desire to take another course in STEM?

Upon conclusion of interview, participant thanked for their participation.

Appendix D. IRB Approval Letter

Below is a screenshot of the IRB Approval Letter covering research in Manuscript 2.

VirginiaTech

Office of Research Compliance
Institutional Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: March 25, 2016

TO: Peter Doolittle, Stephen Michael Biscotte, John Chermak

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: Exploring the nonmajor student experience in introductory STEM courses

IRB NUMBER: **16-305**

Effective March 25, 2016, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**March 25, 2016**
Protocol Expiration Date:	**March 24, 2017**
Continuing Review Due Date*:	**March 10, 2017**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

Conclusion to the Dissertation

Stephen Biscotte

There is a great deal of national attention on improving STEM preparation, retention, and global competitiveness. However, often missing from these discussions and initiatives is the focus on the concrete student experience in the classroom, particularly for those outside 'the STEM pipeline.' A STEM-literate citizenry is critical to support scientists and STEM professionals in addressing societal needs and exploring the natural world. General education often bears the brunt of STEM-literacy preparation as it serves as the one shared experience of all graduates. Therefore, this work was guided by a couple key questions: *what should be the nature of the student experience in the general education science classroom to prepare an engaged citizenry* and, in actuality, *what is it*?

Manuscript 1 provided a review of the literature around the Deweyan aesthetic experience broadly and how it should and is fostered in the science classroom more specifically. It made the case that for students to engage with, do, and learn science on the level that scientists engage with science and for a duration that extends past the bounds of the course, these students would need to undergo transformative, awe-full (not awful), aesthetic experiences in the general education science classroom. Therefore, it was argued that the role of the instructor in these courses is to foster opportunities for students to have these aesthetic experiences, otherwise the student outcomes, no matter how well intentioned, simply cannot be met.

Manuscript 2 provided an empirical inquiry into the overarching questions through a phenomenological exploration of the concrete lived experience of non-STEM major students in an introductory geosciences course. This study found that students were developing the confidence and capacity to engage with conversations on scientific issues both within and beyond the walls of the course, a more nuanced perspective on scientific authority, and connections to prior personal life experiences and interests within the context of course topics and activities. In addition, using the CRISPA framework (Uhrmacher, 2009) to analyze the expressed memorable experiences for components of aesthetic experience, it was concluded that students were having aesthetic experiences. These occurred both within or outside the time and space of the course, with those falling outside the course serving as objects onto which students could ground the course content.

Implications for Practice

Manuscript 1 in no subtle terms argued that it is an absolute necessity for instructors to offer opportunities for students to have aesthetic experiences in the classroom if they want students to learn science. The CRISPA framework (Uhrmacher, 2009) serves as a course design guide for providing a classroom environment that attends to the components of the aesthetic experience. To connect with the world around them, students must actively engage with it using all of his or her senses. With appropriate time and space, a student can go beyond merely recognizing an object but actually perceiving it, 're-seeing' it in a new way. A student who feels empowered to take risks and think imaginatively and creatively can approach problems or questions with an inspired vigor. These components can be attended to both at the course design phase as well as in 'just-in-time' transformative learning opportunities.

Manuscript 2 provided evidence that students were having aesthetic experiences both inside and outside the space and time of the course. To foster in-class aesthetic experiences, instructors should develop activities where students can interact with the material in an active way with space for conversations to prolong and elevate the engagement. To spark student connections to their prior life experiences, instructors should provide texts and media on meaningful topics with real-world implications. These can serve as the seeds for conversations and inquiry beyond the walls of the classroom.

Future Research

A number of philosophical questions emerged regarding the nature of the aesthetic experience. First, are there "negative" aesthetic experiences? According to Dewey (1934), confirmed by personal correspondence with the Deweyan scholar Thomas Alexander (personal communication, March 28, 2014), there really is no "negative" aesthetic experience but rather a dark or grief-filled experience that is "artistically deepened and intensified." Aesthetic experiences are memorable and transformative leading to personal growth as opposed to the anaesthetic that is forgotten and unimpactful… the 'humdrum.' There is no value judgement applied to the experience as growth is growth. This follows the 'what doesn't kill us makes us stronger' perspective. For example, a storm or an illness could allow for an aesthetic experience just as a wedding or painting might. An experience either allows for growth or it doesn't. Only when prescribed goals or outcomes are applied can an experience lead someone toward or away from the goals. So how do we make sense of Jane's experience in her physics class (Roth and Jornet, 2013) that is obviously memorable and transformative but resulted in a complete disengagement with the class and science in general? I imagine through this lens it could be said that Jane grew as a person (handling the frustration or grief of the situation), just not toward the desired outcomes of the teacher (getting an A or even liking science.) Although Manuscript 2 explored the relationship between aesthetic experiences and student desire to pursue further STEM study, all of the experiences had a 'positive' alignment with student engagement with science. Therefore, the philosophical consideration of the relationship between aesthetic experiences ('positive' and 'negative') and their resulting impact on student engagement/interest in science would be warranted.

Also, Manuscript 2 explored the relationship between students having aesthetic experiences and their *desire* to pursue further STEM study. But is there a relationship between the aesthetic experiences and actually pursuing further STEM study or further engagement in science? A longitudinal study could shed light on the impact of having aesthetic experiences on continued engagement with science or "lifelong learning", the noble goal of any university curricula.

Some empirical questions also emerged concerning aesthetic experience. The CRISPA framework (Uhrmacher, 2009) served as a useful guiding framework for exploring the presence of aesthetic experience, a concept inherently difficult to express and even harder to deconstruct. It has been suggested that three of the six components (connections, sensory experience, and active engagement) are fundamental to having *an* experience, while the other three (imagination, perceptivity, and risk taking) perhaps serve to color, intensify, or prolong the experience. Manuscript 2 contended that the components were present in the student descriptions, thus confirming the presence of (or at least the right conditions for) an aesthetic experience. However, are certain components interdependent? Are there varied intensities among aesthetic experiences that could be determined or guided by certain components? To address these questions, an empirical exploration of the framework would provide greater validity and value to its use as an analytical tool.

References

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