A CASE STUDY EXPLORING THE EXPERIENCES OF PRESERVICE TEACHERS IN A LIVE-INTERACTIVE PORTABLE PLANETARIUM PROGRAM

by

BEAU HARTWEG

Bachelor of Science, 2005
Texas Christian University
Fort Worth, Texas

Master of Education, 2011
University of Texas- Arlington
Arlington, Texas

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CHAPTER 1. GENERAL STATEMENT

Introduction

Planetarium research is a continually evolving field, dating back to the mid-twentieth century when planetariums began being installed at educational institutions around the United States (Chartrand, 1973). Much of the research on planetariums has focused on their ability to be used as a tool to promote student conceptual change in various content areas (Brazell & Espinoza, 2009; Lelliott & Rollnick, 2010; Slater, Ratcliff, & Tatge, 2017). With the recent introduction of digital planetarium systems that are capable of creating simulated immersive visual environments (SIVEs) (Sumners, Reiff, & Weber, 2008; Wyatt, 2005; Yu & Sahami, 2007), a new avenue of research has been opened to explore the qualitative nature of these simulated experiences. At the same time, there has been a lack of research examining the planetarium as a tool in preservice teacher education (Slater et al., 2017). The National Research Council ([NRC], 2012) has identified that "preservice teachers will need experiences that help them understand how students think, what they are capable of doing, and what they might reasonably be expected to do under supportive instructional conditions" (p. 257). Therefore, this study seeks to understand the experiences of preservice teachers who participate in a live-interactive planetarium program as part of their educational training.

Earth and Space Science Standards

Recent national reform documents in the United States have called for changes in how Earth and Space Science (ESS) is taught in grades K-12. The Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) has recognized the need for an increased importance to be placed on ESS concepts, which has been reflected by making them a disciplinary core idea in the NGSS. The increased emphasis on ESS is due to the "rapidly increasing relevance of earth science to so many aspects of human society" (NRC, 2012, p. 172). This understanding underscores the need for a connection between the subject-matter and the real world. While some content connections are based on application to real world contexts, they may not be relevant to the everyday experiences of students. However, the NGSS addresses this discrepancy through specific ESS standards that ask students to "use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions" (NGSS Lead States, 2013, p. 176**)**.

The new framework for national science standards (and presented in the NGSS) was prompted by new understandings in science and teaching, and by a movement from states to adopt a set of common standards in other content areas such as mathematics and language arts. The two major goals of the standards include: "(1) educating all students in science and engineering and (2) providing the foundational knowledge for those who will become the scientists, engineers, technologists, and technicians of the future" (NRC, 2012, p. 10). To achieve these goals in line with current understandings and teaching practices, the NGSS standards are built around three dimensions: scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. The disciplinary core ideas are divided into four areas: physical sciences, life sciences, ESS, and engineering, technology, and applications of science. The three dimensions are designed to build over multiple years of schooling, with specific grade band endpoints of what students should be able to understand by the end of grades 2, 5, 8, and 12.

The disciplinary core idea of ESS is one that focuses on the investigation of earth's processes, the earth's place in the solar system and galaxy, and the impact human activity has on the earth. Due to the nature of ESS, many concepts presented in the disciplinary core idea (e.g. forces, energy, gravity, magnetism, human impacts) are connected to other core ideas such as physical and life sciences. These concepts are divided into three core ideas: ESS1- Earth's Place in the Universe, ESS2- Earth's Systems, and ESS3- Earth and Human Activity (NGSS Lead States, 2013). While each core idea is important, the concepts described in ESS1 are of primary interest in the area of planetarium education, and they are the focus of the content discussed.

Core idea ESS1 seeks to provide students with the concepts to be able to answer "what is the universe, and what is Earth's place in it?" (NRC, 2012, p. 173). The concepts covered in this core idea include the universe and its stars, earth and the solar system, and the history of planet earth. By the end of grade 2, students should be able to identify patterns and motion of objects in the sky; observe, describe, and predict seasonal patterns; and understand basic cycles of the earth. By the end of grade 5, students should be able to understand that the sun is a star; know the orbital relationships between the sun, earth, and moon, which leads to observable patterns and cycles such as the phases of the moon; and that the earth has changed over time due to geologic processes. The skills students are expected to have include making and supporting arguments from evidence, and using graphic displays to represent data. By the end of grade 8, students should be able to recognize the structure of the solar system, the effects of gravitational pull to explain orbital dynamics, and that the seasons are a result of the earth's axial tilt. Students are largely expected to be able to develop and use models to represent the different system dynamics covered in this grade band. By the end of grade 12, students should have a deeper understanding of the concepts and understand the life span of the sun in comparison to other stars in the galaxy; describe orbital relationships through physical laws (e.g. gravity, Kepler's Laws of motion); tectonic processes; and how radioactive decay and isotopic content provide ways to identify geologic timeframes from rock formations. The skills students should have by the end of grade

12 include using mathematical or computational models to represent systems, constructing explanations from evidence, and communicate scientific ideas.

In addition to being present in the ESS standards outlined in the NGSS, one of the guiding principles of science education at large is connecting learning to student interests and prior experiences. The framework states that a “rich science education has the potential to capture students’ sense of wonder about the world and to spark their desire to continue learning about science throughout their lives” (NRC, 2012, p. 28). This principle is also discussed by multiple education researchers. For John Dewey (1907), connecting learning with student experience is a critical aspect of education. He wrote that there “should be a natural connection of the everyday life of the child with the… environment about him, and that it is the affair of the school to clarify and liberalize this connection, to bring it to consciousness” (pp. 90-91). For Dewey, it is the role of the school or teacher to find ways to connect learning to meaningful experiences, relatable to everyday life. Gil-Pérez et al. (2002) argue that the teaching strategy most consistent with scientific reasoning involves providing students with problematic situations that are of “possible interest and worthiness” (p. 566) to the students, so that they may feel motivation about the treatment of the situation.

The NRC (2011) also recognizes the importance of technologies to create simulated experiences for connecting learning to student interests in experiences. Many of these simulations have been designed to create experiences that “present the discoveries of [the] 21st-century… with great fidelity and within an accurate three dimensional context” (Wyatt, 2005, p. 15) for audiences. The planetarium is one such tool that can create simulations to help connect student learning and experiences in accordance with recent guidelines and recommendations set forth in national documents.

Planetarium Education

A meta-analysis of research from 1974-2008 found that the majority of planetarium research has been focused on student conceptualizations of content, with 80% of studies addressing topics consistent with the “big ideas” of ESS standards, such as “conceptions of the Earth, gravity, the day-night cycle, the seasons, and the Earth-Sun-Moon system” (Lelliot & Rollnick, 2010, p. 1771). During the late 1990’s and early 2000’s, digital planetarium technology began to emerge that allowed planetariums to create simulated earth- and space-based perspectives to teach ESS content in an immersive visual environment (Sumners et al., 2008; Wyatt, 2005; Yu & Sahami, 2007). While many of the technologies used in creating simulated environments are still relatively new, the NRC (2011) believes there is sufficient evidence to support the use of simulations “to enhance conceptual understanding in science and moderate evidence that simulations can motivate interest in science and science learning” (p. 27). With the recent introduction of new planetarium technologies, an additional avenue of research has been opened to explore the qualitative nature of these simulated experiences. Consistent with this idea, Plummer, Schmoll, Yu, and Ghent (2015) identified that “one broad area of potential research could focus on audience experiences in the planetarium” (p. 10) utilizing new technologies.

The unique educational setting of planetariums requires specialized research. Planetariums can be used to create a learning environment that operates on a spectrum ranging from formal to informal education. The specific environment fostered in a planetarium is dependent on the goals of the planetarium and teaching method used by planetarium educators (Plummer et al., 2015). In more formal planetarium learning environments, the program is educator-led and the “students have little control over what they study” (Plummer et al., 2015, p. 9). Conversely, in informal learning environments, students are provided with a certain degree of choice about what they learn in the planetarium program. Planetariums associated with schools and universities may utilize informal teaching strategies, but follow a more structured formal education format. On the other end, planetariums associated with science centers and museums may offer a more informal approach, where visitors have more freedom to choose a planetarium program that covers a particular subject matter of interest.

Portable planetariums represent another dimension of planetarium education research. Portable planetariums are typically inflatable domes with a central projector that can be brought out to schools and other locations (Plummer et al., 2015). The accessibility of portable planetariums means they can combine informal learning strategies with school curriculum in formal learning environments.

In addition to a variety of settings, there are also multiple teaching methods that may be used within the planetarium. Full-dome movies are one such method, characterized by providing audiences with an immersive movie-like experience that has seen an increased demand in planetariums (Lantz, 2011). The reason for the popularity of full-dome movies in planetariums can be attributed to their ability to provide audiences with a wide diversity of content, combined with their relatively low-cost and ease of use (Bruno, 2008). Additionally, museums and other organizations can use a common suite of planetarium software to develop and distribute their own full-dome movies to audiences worldwide (Bruno, 2008). Live-interactive programs are another type of educational method used in planetariums. Live-interactive planetarium programs may utilize full-dome planetarium software, but there are several characteristics that distinguish live-interactive programs from full-dome planetarium movies. First, there is a focus on audience participation through a variety of activities designed to encourage audience involvement (Friedman, Schatz, & Sneider, 1976). Additionally, the planetarium educator engages in “extensive verbal interactions with other audience members” (Friedman et al., 1976, p. 4). There are also a variety of techniques that planetarium educators can use in live interactive programs, including conversational dialog, questioning the audience, kinesthetic activities, props, and combining digital movies with live presentation (Small & Plummer, 2010). This variety of teaching methods combined with the immersive domed setting makes the planetarium a unique educational tool.

Significance of Study

This study is of significance to the science education and planetarium education communities. In the context of the science education community, there has been an increased emphasis placed on ESS standards through national reform documents. Additionally, preservice teachers should be given experiences that prepare them to teach content-aligned standards and crosscutting concepts expected of students (NRC, 2012). Therefore, it is important to understand the experiences of preservice teachers, and the impact of those experiences. The planetarium is one tool that can provide a suitable experience for preservice teachers. Currently, much of the existing planetarium research has focused on student conceptions at the K-12 and undergraduate levels (Brazell & Espinoza, 2009). Since 1990, there have only been 3 empirical studies that have looked at the use of planetariums in preservice teacher education (Slater et al., 2017). The focus on those studies has been on astronomical conceptions (Baxter & Preece, 2000), and confidence in teaching practices (Ferry, 1995; Maher, Bailey, Etheridge, & Warby, 2013). This study fills a gap in the literature by expanding the research to include the experiences of preservice teachers in a planetarium as part of their content education.

Additionally, this study adds to the knowledge base of the planetarium community. Currently, there are limited empirical studies related to the field of planetarium education. A recent review of the literature found that while there are many articles related to planetarium education, there are only 86 papers in the field that can be considered empirical research (Slater et al.). From these studies, only 15% (n=13) use qualitative research methods (Slater et al., 2017). By utilizing qualitative methods to examine the experiences of participants in a planetarium, this study hopes to make significant contribution to the field.

Finally, even though there has been much research conducted and a general consensus reached regarding the effectiveness of planetariums to teach ESS content to students (Brazell & Espinoza, 2009; Lelliott & Rollnick, 2010), there is still wide spread discussion regarding the pedagogical methods that best serve audiences in the planetarium. Some planetarium education researchers have proposed using full-dome movies in the planetarium as an effective way to promote student conceptualizations (Elvert, 2015; Law, 2006; Sumners et al., 2008; Wyatt, 2005; Yu, 2005). Others have suggested that planetarium shows that incorporate live-interactive components, whether in whole or in part, are effective means for developing student conceptions of ESS content (Bell, 1993; Berglund, 2011; Chastenay, 2016; Neece, Sayle, Nleya, & Boyette, 2013; Small & Plummer, 2014). Surveys have also shown that many planetarium educators "want educationally oriented programs that offer the opportunity to interact with their audiences" (Small & Plummer, 2010, p. 8). If planetarium technology is to be used to deliver live-interactive presentations to students and audiences, it will be important to understand the quality of the experiences created by this method.

Research Questions

In light of the increased emphasis placed on ESS content with national standards in addition to the recent technological developments and pedagogical discussions within the field of planetarium education, the purpose of this research project is to answer the question: What are the experiences of preservice teachers who participate in a live-interactive portable planetarium program that uses a simulated immersive visual environment? The research question also contains the following sub questions:

1) In what ways do preservice teachers participate in/ interact with a live-interactive portable planetarium program?

2) How do preservice teachers describe their experiences after participating in a live-interactive portable planetarium program?

3) What connections to outside events or experiences do preservice teachers make after participating in a live-interactive planetarium program?

4) In what ways are the experiences of preservice teachers in the planetarium educative, noneducative, or miseducative?

Definition of Terms

For this study, it is important to define the following terms that may have situated meanings and, therefore, need clarification. The terms include:

Portable Planetarium. An inflatable domed structure that includes a projector capable of displaying images of the night sky and other digital imagery. Audiences sit on the floor in a concentric pattern. The portable planetarium can be moved and set up in a variety of locations.

Live-Interactive Planetarium Program. A method of teaching within a planetarium space in which the educator interacts with and engages participants through a variety of methods, including but not limited to conversational dialog, questioning the audience, kinesthetic activities, props, modeling, and combining digital movies with live presentation.

Simulated Immersive Visual Environment. A digital visual representation of an environment (e.g. the night sky as seen from earth, the solar system as seen from space) presented in such a manner that the viewer may have a reasonable feeling they are a part of that environment.

Experience. The working definition of experience for this research includes both an active and passive element. The active element is defined as any action or form of participation that occurs within the planetarium, and the passive element is defined as any form of mental reflection or connection made as a result of the active element.

Educative Experience. An experience that leads the participant to articulate a set of facts or ideas consistent with, connected to, or related to activity in the planetarium.

Miseducative Experience. An experience that leads the participant to articulate a set of facts and ideas that are incorrect, or are inconsistent with activity in the planetarium

Noneducative Experience. An experience where the participant is unable to articulate a set of facts or ideas, or they are not connected to or related to activity in the planetarium.

CHAPTER 2. LITERATURE REVIEW

Three main bodies of literature are reviewed. First, this section examines educational theories relating to the concept of experience in detail, with an emphasis on John Dewey's views of experience in the context of current national science education standards. Furthermore, literature pertaining to the educational uses of the planetarium is presented, with a focus on the use of SIVEs and live-interactive planetarium teaching methods. Finally, this chapter reviews the literature regarding preservice teacher education in ESS content.

Experience & Educational Theory

With the development of national science education standards by the NRC (2012) that were designed to provide students with experiences to "actively engage in science and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas in these fields" (p. 10), it is worthwhile to review the works of John Dewey and other educational researchers who have examined the role of experience in education. Dewey's educational theory developed over the course of his life and through his extensive writings. His writings include ideas on the roles of individuals such as teachers and students, the social role of education in a democratic society, and the role of experience in education. Other researchers have expanded views of experience by focusing on sociocultural aspects and connecting student interests to learning.

Dewey and Experience

Dewey's educational theory holds relevance today as a lens by which to examine current national standards regarding ESS, as well as to inform planetarium education research. One consistent theme throughout Dewey's educational theory is a focus on growth, and his belief that "the educative process is a continuous process of growth, having at its aim at every stage an added capacity of growth" (Dewey, 1916, p. 63). In *Experience & Education*, Dewey (1938) noted "the soundness of the principle that education in order to accomplish its ends both for the individual learner and for society must be based on experience" (p. 89). Dewey (1916) wrote that experience is twofold, "includ[ing] an active and a passive element peculiarly combined" (p. 73). A Deweyan definition of experience is not only defined by activity, but must also include a cognitive process as a result of the activity. More deeply, however, a Deweyan definition of experience "involves learning that consciously connects consequences with the initial activity or action" (Simpson, Jackson, & Aycock, 2005, p. 51). In addition, Dewey (1958) did not view experience as being something separate from nature, or the real world. As such, his educational theory incorporated this concept of experience and its impact on the roles of the teacher, the student, and the curriculum, which still have relevance today regarding the teaching and learning of ESS content.

When looking at the concept of experience through a Deweyan lens, "everything depends upon the quality of the experience which is had" (Dewey, 1938, p. 27). Dewey noted that there are an abundance of experiences, but often times "they are wrong and defective from the standpoint of connection with further experience" (p. 27). He would see many rote habit activities, such as reciting multiplication tables or avoiding cracks in the sidewalk, as lacking educational worth (Glassman, 2001). The quality of the connection made as a result of the activity is of importance in determining the value of the experience. Additionally, while growth is another key component to an educative experience, Dewey was concerned with the direction of that growth. Dewey noted that it is possible for burglars or corrupt politicians to have experiences that lead to growth in those arenas, but he is clear to state that "when and *only* when development in a particular line conduces to continuing growth does it answer to the criterion of education as growing" (p. 36).

In defining the quality of experience, Simpson et al. (2005) describe Dewey's view on the continuum of experience, which includes: anesthetic experience, non-aesthetic experience, experience, *an* experience, and aesthetic experience. Both anesthetic and non-aesthetic experiences would tend to be classified as non-experiences from a Deweyan sense, due to their lack of meaningful activity, or of forming meaningful connections based on activity. The standard type of experience in the continuum contains both active and passive elements, and while some connections are made they tend to be limited in scope and often lost due to distraction or apathy (Dewey, 1958). Moving along to what is referred to as *an* experience is a type of experience that is memorable. The experience is "integrated, fulfilling, rounded out, whole, self-sufficient, and consummated" (Simpson et al., 2005, p. 136), and as a result of the experience, the individual ends up with a new perspective. Beyond *an* experience, is aesthetic experience. Aesthetic experience involves "a degree of completeness of living in the experience of making and of perceiving" (Dewey, 2005/1934, p. 27). This level of experience involves the active participation of making or doing that leads to a transformative experience where the consequence of the activity is having a new, and perhaps deeper, understanding than before. With an understanding of the types of experience discussed by Dewey, it is possible to examine his views on the impact of experience on curriculum, teachers, and learning in the context of current educational standards.

Experience and Curriculum. Throughout much of Dewey's writings is the importance of experience in the curriculum. One of Dewey's concerns during his involvement with the Laboratory School at the University of Chicago was understanding the extent to which experience was appropriate to the curriculum for developing children (Simpson & Jackson, 1996). Dewey thought that the subject-matter of science had suffered from incorporating experience because it "has been so frequently presented just as so much ready-made knowledge … rather than as the effective method of inquiry into any subject-matter" (Dewey, 2010/1910, p. 102-103). Dewey saw that the process of inquiry that was valid for science could be applicable to all curricular areas, not just science.

It was also important to Dewey that subject-matter experiences not be removed from everyday life. Dewey's Laboratory School sought to find a way "to unify, to organize education, to bring all its various factors together, through putting it as a whole into organic union with everyday life" (Dewey, 1907, p. 107). According to Dewey (1938), a student's introduction into the laws and facts of subject-matter should be "through acquaintance with everyday social applications" (p. 80). The reason for Dewey's stance on the connection between everyday life and subject matter was he saw no distinction between the two.

> Anything which can be called a study, whether arithmetic, history, geography, or one of the natural sciences, must be derived from materials which at the outset fall within the scope of ordinary life-experiences. (Dewey, 1938, p. 73)

Dewey saw the basis for subject-matter curriculum as being derived from real-world experience. The notion of uniting content and experiences with the realities of everyday life is a key theme throughout Dewey's writings on the need for a curriculum that incorporates experience, rather than isolates it from the subject-matter.

Many of the themes found in Dewey's ideas of curriculum are also found in the guiding principles of the national science standards for ESS. First, it is important to note that one reason for an increased emphasis on ESS in the national standards is due to awareness of the "rapidly increasing relevance of earth science to so many aspects of human society" (NRC, 2012, p. 172). This understanding underscores the need for a connection between the subject-matter and its connection to the real world, for which Dewey advocates. While some of the connections between ESS are based on a connection to real-world contexts, they may not be applicable to the everyday experiences of students. However, making some of these everyday connections are present in the specific standards that ask students to "use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions" (NGSS Lead States, 2013, p. 176**)**. This specific science and engineering practice addressed in the standards is referring to making observations of the patterns of the motions of celestial objects, such as the sun, moon, and stars. As opposed to presenting this topic as an abstract concept, the standards are asking students to make through firsthand observations based on everyday phenomena and use that to describe patterns. This is an example of the active and passive elements from Dewey's definition of experience being used in curriculum standards.

Dewey's view that science should not be taught as just a set of facts, but as a "method of inquiry" (Dewey, 2010/1910, p. 103), is also reflected in the framework for the national science standards. The framework places an increased emphasis on scientific and engineering processes as one of the three dimensions in the standards. Additionally, it asserts that scientific and engineering practices should not be isolated from the content, stating that:

> When such procedures are taught in isolation from science content, they become the aims of instruction in and of themselves rather than a means of developing a deeper understanding of the concepts and purposes of science. (NRC, 2012, p. 43)

This approach of integrating subject matter with practices and methods of inquiry aligned with that field are consistent with many of Dewey's ideas of curriculum development.

While the basis for much of the national science standards as a whole are consistent with Dewey's ideas, there are some inconsistencies when looking particularly at the ESS standards. Early grade-level standards are focused on observations and connections with everyday experiences; however, as the content advances some of those connections are no longer emphasized. Instead, the emphasis becomes more abstract based on concepts that deal with large timescales, such as the theory of tectonic plates, and the formation of the Universe and galaxies. While it is the nature of ESS content to deal with such matters, as the concepts become more advanced and more abstract, the role of the teacher to help create those connections to everyday life will become more important.

Experience and Teaching. In addition to the curriculum, Dewey discussed the importance of the role of the teacher in education. Throughout his writings, Dewey used many analogies to describe the role of the teacher, which included *learner, intellectual leader, partner and guide, wise parent, social servant, prophet,* and *artist* (Jackson & Simpson, 1995). These various roles describe the importance of a teacher's ability to continually grow and develop so that s/he can create an environment that allows for student growth in a socially conscience manner, by providing educative experiences and avoiding noneducative or miseducative experiences where possible.

Dewey's discussion of the role of the teacher also included his ideas on the responsibility placed on the teacher for creating an environment conducive to educative experiences. Dewey (1938) identified that "a primary responsibility of educators is that they not only be aware of the environing conditions, but that they also recognize in the concrete what surroundings are conducive to having experiences that lead to growth" (p. 40). This process begins with the teacher first identifying "the native and social experiences of the student" (Simpson et al., 2005,

p. 79). After so doing, the teacher may then create an appropriate environment in which educative experiences can occur. However, at this point, the teacher must also act as a guide for students, as experiences may become miseducative without proper direction (Simpson & Liu, 2007). According to Dewey, students "grow as they are cultivated by respecting and caring educators, teachers, and others" (Dewey, 2008/1926, p. 59). This task is not always straight forward, and there is no singular template for teachers to follow. For Dewey, it is the important responsibility of the teacher to understand their students in order to create the environment for educative experiences to occur.

The supporting documents put forth by the NRC (2007) do not discuss the roles of the teacher as extensively as Dewey did, but they do share some similarities. First, the documents recognize, as Dewey did, the importance for teachers to be learners of their profession, both in terms of content and their students. The NRC (2007) identifies that "teachers' understanding of how students learn has important implications for how they structure learning experiences and make instructional decisions over time" (p. 301). Implicit in this statement are Deweyan ideas for both the need for teachers to be learners of their students, as well as the importance of creating learning environments and experiences that support student learning. Additionally, the NRC documents support the teacher's role as a guide. In line with the idea that experiences may become miseducative without proper guidance, the NRC (2007) notes that "students left free to explore… may continue to face [many] obstacles, interfering with their ability to learn through inquiry" (p. 271). Instead, the NRC recommends that teachers provide students with instructional scaffolds that include guidance throughout scientific inquiry processes. While the NRC may not offer up stances, like Dewey, of the role of the teacher as a prophet or artist, it is clear that many of Dewey's ideas regarding the role of the teacher are present in the national documents supporting science standards. It is important to remember, though, that despite all the effort that the teacher may put into creating the opportunity for educative experiences, learning through experience is ultimately a personal matter for the student (Simpson et al., 2005).

Experience and Learning. When Dewey discussed learning, he was concerned with the direction, or continuity, of growth that occurred as a result of experience. For Dewey (1938), experience itself was not what led to learning, since he believed that “every experience is a moving force” (p. 38). Instead, he used “continuity as a criterion by which to discriminate between experiences which are educative and those which are mis-educative” (Dewey, 1938, p. 37). Dewey labeled experiences that produced an undesired continuity as miseducative. It is only the experiences that lead to a positive continuity that Dewey would consider to be educative. Additionally, according to Dewey (1938), it was not enough to have a series of educative experiences. Instead, he believed they needed to be “related intellectually to those of earlier experiences … and there be some advance in conscious articulation of facts and ideas” (p. 75). It was this continuity of growth from experiences that defined learning for Dewey.

Dewey viewed learning as an ever-evolving process. He described how learning is a “continuous process of reconstruction of experience” (Dewey, 1938, p. 87). With new experiences, the learner faces obstacles and disequilibrium before reaching a new and deeper understanding (Simpson & Liu, 2007). Additionally, learning looks different as the learner matures and develops. Starting in the early years, learning is mainly physical, followed by increasing imagination and indirect thought, and developing to more reflective thought (Dewey, 2010/1937).

One way that the ESS standards align most richly with Dewey’s theory of learning involves his concept of continuity. The NRC (2012) states:

> To develop a thorough understanding of scientific explanations of the world, students need sustained opportunities to work with and develop the underlying ideas and to appreciate those ideas' interconnections over a period of years rather than weeks or months. (p. 26)

This concept has led to the of use learning progressions to provide an understanding of how conceptual knowledge should advance over time. Additionally, the ways in which students are expected to learn changes as they mature and develop. Younger students are expected to be able to make direct observations in regard to the amount of daylight at different times of the year, whereas middle school students are expected to develop representative models of the same scenario, and high school students are expected to use mathematical calculations to describe the same phenomena (NRC, 2012). This is similar to how Dewey viewed the way learning occurs as development matures.

Additional Theorists

As Dewey did not view experience as being separate from nature, many researchers have expanded this view of experience to include that it is also inseparable from sociocultural factors. According to the NRC (2012), "science is fundamentally a social enterprise, and scientific knowledge advances through collaboration and in the context of a social system" (p.5). Both Lemke (2001) and Leach and Scott (2003) support the idea of learning science within a sociocultural context. They agree that a constructivist approach, where knowledge is constructed through social experiences with an understanding of societal influence, is one way for students to learn science.

Vygotsky also viewed experience and culture as interchangeable ideas (Glassman, 2001), and he discussed the collaborative nature of learning with his sociocultural constructivist theory.

A key component of Vygotsky's (1978) theory is the zone of proximal development, which explains the importance of collaboration with a more knowledgeable other to fill in the cognitive cap between what an individual is capable of accomplishing alone and what can be achieved through interaction with others. Through social collaboration with an expert, the learner is able to "participate in new tasks, to learn new skills, … [and] learn new ways of using language" (Gibbons, 2006, p. 26). The NGSS frameworks (NRC, 2012) reflect this idea by stating that "[experts] helping students learn the core ideas through engaging in scientific and engineering practices will enable them to become less like novices and more like experts" (p. 25).

Wenger (2000) expanded on this idea of social learning with the concept of communities of practice. According to Wenger, learning is a social process, and knowing "is a matter of displaying competences defined in social communities" (p. 226). The degree to which these communities continue to learn is determined by the level of initiative of keeping learning a priority, the level of mutual engagement by community members, and how well the community reflects on the effects of its practices.

Dewey (1958) also recognized that the desire to learn begins with prior experience, and additional research has expanded on this concept by focusing on connecting student learning to experiences and interests. While finding ways to connect student learning to their interests is a critical role of the teacher, Lemke (2001) discusses the sociocultural aspects that influence student interests and attitudes towards science as well. He asserts that "community beliefs, acceptable identities, and the consequences for a student's life outside the classroom (and inside it)" all impact how students respond to a teacher's "well-intentioned but often uniformed efforts at directing their learning" (Lemke, 2001, p. 301). Lemke continues by positing that unsuccessful attempts to connect students to learning is often not a result of students failing to understand a scientific concept, but whether societal factors make it worthwhile to engage in the learning process.

Barton and Berchini (2013) discuss possible ways to take a sociocultural approach to connecting learning with student experiences and interests. The first approach they suggest is active position, which involves becoming aware of student interests and experiences by taking an active role in getting to know the students. In doing so, it is then possible to design lessons that are able to connect science content objectives to student interests and experiences. A second approach is critical navigation. In this approach, the teacher finds ways to incorporate the students' lived experiences into science education, and encourage students to identify and challenge forms of oppression that limited or prevented them from participating in science. The authors acknowledge there are a multitude of ways for teachers to connect with their students and interests beyond what they propose, but the critical component is that teachers must be willing to become "learners of their students and participants in the community" (Barton & Berchini, 2013, p. 27).

Planetarium Education

Simulated Immersive Visual Environments

The term *immersive visual environment* can relate to a variety of contexts, including online simulations, video games, virtual reality, and multi-channel screen displays; however, planetariums represent a distinct environment due to their ability to provide a wide field-of-view experience simultaneously to many people (Fraser et al., 2012). In the early 2000's the development and introduction of high quality video projectors in conjunction with computer hardware capable of rendering high quality three-dimensional imagery allowed for SIVEs to be introduced into the domed planetarium space (Wyatt, 2005). The types of visuals created in the planetarium can be used to present a wide variety of content, which can include (but is not limited to) depictions of the night sky from an earth-based perspective, three-dimensional modeling of the sun-earth-moon system from a space based perspective, detailed visualizations of planets and other celestial objects, and examining scale of objects (Yu, 2005).

The extent to which an environment can be considered immersive is determined by a multitude of factors. One key factor is the concept of illusion, which can include feeling actually present in the place being simulated or accepting the plausibility that what is being presented could be occurring (Schnall, Hedge, & Weaver, 2012; Slater, 2009). The effectiveness of the illusion created in the planetarium can be influenced by the visual presentation, such as the quality of images, resolution of the projector, frame rate, and field of view (Schnall et al., 2012). In addition to detailed visual presentations, the immersiveness of the environment created can be influenced by additional elements such as the role of sound/music, the quality of storytelling either through a recorded narrator or live presenter, and a peaceful/relaxing atmosphere (Croft, 2008). Social factors may also play a role in the immersive experience, due to the planetarium's ability to create an environment that is displayed a large group of people at the same time (Yu, 2005). As such, immersive planetarium programs can include social facilitation and collaboration among participants and with the educator (Schnall et al., 2012).

Research has indicated the three-dimensional images created in the planetarium can have an impact on long-term student retention of content. Zimmerman, Spillane, Reiff and Sumners (2014) conducted a study comparing student learning on human space flight concepts after a lesson in either a classroom or planetarium setting. Their results showed that while there were immediate conceptual gains after participation in both programs, those students who participated in an immersive planetarium environment had significantly better scores on a content test administered six-weeks after the lesson than those who only participated in the classroom program.

Simulated environments have also been shown to "allow students to make accurate observations of phenomena that could otherwise be completed only in the real world or in some cases not at all" (Bell & Trundle, 2008, p. 348). One ESS concept that planetariums are capable of addressing through simulated observations is celestial motion. Prior research has shown that children create mental models in attempt to understand the physical world even before they are formally taught specific concepts (Vosniadou & Ioannides, 1998). When creating a conceptual model of the motion of the earth, sun, moon, and stars, children often visualize the celestial objects being located above a flat earth, moving up and down during the day/night cycle (Vosniadou & Ioannides, 1998). This issue of students developing accurate models of celestial motion is a disciplinary core idea addressed in the NGSS ESS1 standard, which maps out that by grade 5 students are asked to develop accurate graphical representations to describe celestial motion (NGSS Lead States, 2013). The difficulty for children in developing an accurate mental model of celestial motion may be related to their lack of ability to spatially interpret three-dimensional information from the two-dimensional representations they are exposed to with traditional classroom teaching methods (Plummer, Kocareli & Slagle, 2014). Providing students with a SIVE to observe the motion of celestial objects in three dimensions is one way planetariums can help students develop more accurate models.

SIVEs in the planetarium may also be used to teach ESS content, such as seasons. Yu, Sahami, Sahami, and Sessions (2015) studied the impacts of using immersive visualizations in a planetarium for teaching seasons to undergraduate students. The study found significantly higher performance on multiple-choice quizzes and curriculum tests from those students who viewed the visuals in the planetarium when compared to those who viewed two-dimensional visuals in the classroom and the control group who had no experience with visualizations. The results allowed the researchers to conclude that there are several benefits to the visuals created in an immersive environment. The first is the ability to “accurately represent the true scale, orientation and position of Solar System objects” (p. 41), as well as show time variables. In so doing, students may be provided with accurate models that contradicts common misconceptions, such as that the seasons are a result of earth’s distance from the sun rather than axial tilt. Additionally, the planetarium can be used to present students with multiple frames of reference, including earth-based and space-based perspectives, which may aid in a more holistic understanding of astronomical concepts.

Research has also shown the experiences created with SIVEs can lead to high satisfaction, and increased interest in the subject matter presented. One study examined the experiences of visitors attending one of a series of planetarium experiences that combined high-quality visualizations, music, and content focused on astrobiology (Yu, DeMarines, & Grinspoon, 2014). The study found that a significant portion of visitors found the experience to be better than expected, and were more interested in learning more about the science presented after the program.

Live-Interactive Planetarium Programs

The use of live-interactive teaching in the planetarium is not a new concept, and has previously been referred to as a “participatory oriented planetarium” (Mallon & Bruce, 1982, p. 53). Before the introduction of high-quality digital systems in the planetarium, research studied the impacts of live planetarium teaching such as the role of audience participation (Friedman, Schatz, & Sneider, 1976), storytelling (Meader, 1993), and humor (Fisher, 1997). Additional research found that including verbal interaction activities with audiences in the planetarium had a greater impact on their understanding of constellations and attitudes about astronomy than a more lecture-based star show (Mallon & Bruce, 1982).

More recently, many planetariums have begun to combine digital systems capable of SIVEs with live-interactive programs, which can include a variety of methods and teaching strategies. A survey of planetarium educators found that the teaching methods consistent with live-interactive programs could be classified into four categories: use of questions, dialog, physical interaction (e.g. kinesthetic activities, use of props, modeling), and general engagement (e.g. use of inquiry and exploration, communication style, humor, eye contact) (Small & Plummer, 2010). One study examining the ways planetarium educators teach found similar results, with educators using a variety of strategies including questioning, explanation, kinesthetic activity, modeling, observation and identification skills, reinforcement, prediction, and storytelling (Hartweg, 2016).

Additional technologies have begun to allow audiences to interact with the planetarium in other ways. Reid et al. (2014) conducted a study allowing undergraduate students to direct the motions of a planetarium program using an off-the shelf video game controller. Additional methods of interactivity can involve using camera imaging systems or multi-touch tablet to interact with planetarium software (Tuveri, Iacolina, Sorrentino, Spano, & Scateni, 2013), interactive pointing systems (Soga, Matsui, Takaseki, & Tokoi, 2008), and augmented reality using smartphones (Sumners, 2017).

Research has also been conducted on the impacts of live-interactive planetarium programs. In a study conducted by Neece et al. (2013) no significant correlation between the level of interactivity of participants and learning outcomes on a pre- post-test assessment was found. The authors note, however, that their findings may have been impacted by limited participants and too few presentations. Additionally, the characteristics of different presenters such as speed of presentation style, specific teaching objectives, and comfort with the program may have impacted results, which were not accounted for in the study.

Another study found that high levels of interactivity in the planetarium were not effective for first-year undergraduate students who were allowed to control the planetarium programs with little guidance from the educator (Reid et al., 2014). The authors found no significant difference in conceptual gains between the 20-30 minute, interactive, student-led planetarium show and the non-interactive program led by a teaching assistant. While students reported enjoying the experience and seeing value in the planetarium as a learning tool, they expressed the need for additional guidance and instruction on how to use the control before meaningful learning could occur. Therefore, Reid et al. (2014) recommend additional scaffolding on the part of the instructor when facilitating interactive planetarium shows.

Portable Planetariums

Portable planetariums are flexible domed spaces, capable of reaching diverse audiences who may not otherwise have access to a planetarium. In addition, portable planetariums can use different methods of projection such as canisters to optically represent the stars of the night sky, or digital computer and projection systems with either a fish-eye lens or domed-mirror system that can represent a wide variety of content. Portable planetariums also use a variety of inflatable dome sizes that can serve different sized audiences, from small domes that can fit classes of 10-15 students to large domes that can fit upwards of 100 people. Consistent with this idea of flexibility, one study found that portable planetarium educators at an informal science education center were conscious of a multitude of factors such as space limitations, technology, and audiences, and they adjusted their teaching strategies accordingly (Hartweg, 2016).

Recently, there have also been multiple studies to understand the effects of portable planetariums. Sumners et al. (2008) conducted research with a portable planetarium that can be taken to schools. Their study examined how students' conceptual knowledge of earth science were impacted after experiencing a 22-minute prerecorded full-dome planetarium movie. The students in this study ranged in age from 3-12 years old. Results from the study showed that planetariums can be useful in creating an "immersive environment" (Sumners et al., 2008, p. 1848), which may increase student engagement and facilitate concept exploration. The authors found that the immersive experience created by using a full-dome movie is useful in helping students understand earth and space science concepts that have a three-dimensional component.

Carsten-Conner, Larson, Arseneau, and Herrick (2015) conducted research in a portable planetarium using live-interactive teaching methods. The study looked at the impact on 4th-grade student conceptions of celestial motion after a 25-minute portable planetarium show. During the planetarium program, the presenter provided students with both an earth-based perspective that included a simulation of the night-sky, and a space-based perspective that included visual images of planetary orbits. Students were administered a pre- and post-survey that asked students about celestial motion, day/night cycle, seasons, planets, and constellations. Results from the study showed significant gains in celestial motion content knowledge except for day/night cycle, which saw a decrease from pre- to post-survey. The authors explain that this decrease may have been a result of prior student misconceptions, confusion because of the presentation, or confusion regarding the way the question was presented. Overall, however, the authors conclude that participation in a portable planetarium can aid students' development of celestial motion content knowledge, particularly as a result of the visual and immersive nature of the planetarium that links presentation of astronomical concepts with participant observations.

Chastenay (2016) conducted a study that examined how a live interactive portable planetarium program was used to teach the concept of the lunar cycle to students 12-14 years old. The study combined a planetarium program with student observations of lunar phases for one month prior to the planetarium show to allow them to have a real-world context for the content taught in the planetarium. Within the study, the educator used the digital planetarium software to create a “highly realistic simulation” (p. 6) of a space-based perspective of the moon. The space-based perspective shown in the planetarium created a discrepant event between what students observed prior to the planetarium and the simulation. The planetarium educator used a live interactive teaching style that included didactic methodology, and students were asked to develop potential explanations for the discrepancies between what they observed outside and in the planetarium show. In addition, the educator asked students to make predictions about the position of the moon, and then compare their predictions to the simulation of the motion of the moon as seen in the planetarium. The researcher concluded that this method of using a live interactive planetarium program in combination with student observations aided students in developing conceptual understanding of lunar models and applying that knowledge to make predictions regarding lunar position and phases.

Preservice Teachers

When using a planetarium in preservice teacher instruction, it is important to review the literature regarding preservice teacher understandings of ESS concepts. A wealth of research has shown that often preservice teachers hold many deep-seated misconceptions about astronomy concepts such as celestial motion, seasonal changes, phases of the moon, and the day/night cycle

(Abell, Martini, & George, 2001; Atwood & Atwood, 1995; Bell & Trundle, 2008; Parker & Heywood, 2008; Plummer, Zahm, & Rice, 2010; Trumper, 2003; 2006; Trundle, Atwood, & Christopher, 2007). One study suggests that models may be useful in impacting preservice teacher conceptions regarding the day/night cycle. Those preservice teachers who were able to explain the cause for the day/night using models were more likely to express the concept consistent with established scientific canonical knowledge, whereas those who were asked to provide a written explanation were more likely to express alternative conceptions (Atwood & Atwood, 1995). Another study found that preservice teacher ESS conceptions improved after a nine-week long open-inquiry unit that involved investigating an astronomical concept, making and recording observations, and developing an explanation for the phenomenon; however, results also showed that teacher conceptions only improved for the specific phenomenon observed, and not for other concepts presented by fellow students (Plummer, et al., 2010). While making real-world observations over an extended period may help develop understanding of ESS concepts, another study looked at preservice teachers using computer software to simulate observations (Bell & Trundle, 2008). Using the software, preservice teachers made observations of the moon on different dates, focusing on time, date, location, shape, and its position in relation to other objects in the sky (e.g. the sun and stars). Results from the study showed the ease of using software to simulate making observations over many nights and months may have improved preservice teacher conceptions of moon phases (Bell & Trundle, 2008). These instructional methods that have been shown to have an impact on preservice teacher understanding of ESS concepts (using models, making observations, and simulating observations over an extended period of time) are possible to be conducted within a live-interactive domed-planetarium, and therefore it is appropriate to use a planetarium as a part of a preservice teacher education program.

Because of the low number of empirical planetarium education studies, there are an extremely limited number of studies involving preservice teachers and domed-planetariums, making up less than 5% of all published articles in the field since 1965 (Slater et al., 2017). The focus of these studies has primarily been on understanding the self-efficacy impacts of preservice teachers using a planetarium as a teaching opportunity. One study found that preservice teachers who taught students while using a planetarium improved their own conceptual understanding of astronomy concepts (Baxter & Preece, 2000). Another study found that after teaching a planetarium program to school aged-children, preservice teachers had an increase in confidence and self-efficacy about teaching (Maher et al., 2013). Since the current research on planetariums and preservice teacher education focuses primarily on methodological concerns, this study expands the knowledge base by understanding the experiences of preservice teachers participating in a planetarium as a part of their content-related education.

Conclusion

This study is informed by several fields of research. Dewey's educational theory holds relevance today as a lens by which to examine current national standards regarding ESS, as well as to inform planetarium education research. Much of his writing on education was based on the idea that experience is an essential part of educational growth. For Dewey, an experience must include an active element followed by a passive element that reflects on and creates meaning as a result of the activity. However, for an experience to be educative it must also have a positive continuity that leads to growth. The NRC (2009, 2011) also recognizes the importance of technology-based simulations in helping students learn science. Research has shown that the planetarium can be an effective tool to engage students in learning, and help students develop accurate conceptual models, particularly regarding celestial motion. Portable planetariums may, therefore, be one way to use SIVEs to provide educative experiences when teaching ESS content to preservice teachers.

CHAPTER 3. METHODOLOGY

The purpose of this study was to develop a better understanding of the types of experiences preservice teachers have in a live-interactive planetarium program, and how those experiences influence their thoughts and actions. Because the research investigated the nature of students' experiences, this study used a qualitative research design. While developing conceptual understanding of ESS content is one objective of a lesson in the planetarium, the scope of this research did not assess gains in student knowledge. Rather, this study examined the ways students describe their experiences in a planetarium, the types of interactions students have in a live-interactive setting, the connections they make as a result of the experience, and the quality of the experience. A qualitative design fit the goal of this study, as it is an interpretive form of research that can make contributions to the existing base of knowledge by "capturing stories to understand people's perspectives and experiences" (Patton, 2015, p. 12).

Theoretical Framework

Researcher Lens

When researching the concept of a meaning-laden word such as "experience" it is important to discuss the lens through which that word is explored. This study uses a Deweyan lens to view the types of experiences students have during a live-interactive planetarium program. Dewey (1916) defined experience as not only being the result of participating in an activity, but also as including a passive element in which there is reflection and a connection between the activity and the effects (consequences) that follow. Consistent with a Deweyan view of experience, the working definition of experience for this research includes both an active and passive element, as defined in Chapter 1. This understanding of experience informed later analysis of data in this study when identifying whether an experience had occurred, since both elements must have been present to be considered an experience.

In addition to discussing experiences, Dewey was concerned with the quality of the experience to differentiate educative experiences from noneducative or miseducative experiences. Therefore, a study that uses a Deweyan lens to examine experiences should focus on the qualitative nature of the types of experiences. Dewey (1938) described how continuity of growth is the measure by which to describe an experience as educative. Educative experiences are ones that are “related intellectually to those of earlier experiences… and [include] some advance in conscious articulation of facts and ideas” (p. 75). These definitions of types of experience informed analysis of the data when answering research sub-question four. Within the context of this study, the quality of experiences was identified based on a continuity of growth and rated as educative, noneducative or miseducative as defined in Chapter 1.

Paradigmatic Framework

Within the qualitative research design, this study used a social constructivist paradigmatic framework. The social constructivist perspective takes an ontological stance of relativism, and assumes that “multiple realities are constructed through our lived experiences” (Creswell, 2013, p. 36). This assumption leads to the rejection of an absolute truth since what is known or real is based upon a social construct (Duit, 1996), and realities “only exist in the minds of the persons contemplating them” (Lincoln & Guba, 2013, p. 39).

The epistemological stance of social constructivism assumes meaning is co-constructed between the researcher and participants (Creswell, 2013; Lincoln & Guba, 2013; Schwandt, 2015). Knowledge is constructed based on a multitude of factors such as historical and sociocultural contexts, prior experiences, language, and shared understandings (Schwandt, 2015).

Within these various contexts constructed meanings can serve as the foundation of knowledge (Lincoln, Lynham, & Guba, 2011). Researchers using this framework take the assumption that knowledge is created rather than discovered, and it is a subjective form of knowledge that is based on persons and the interpretations made based on surrounding contexts (Lincoln & Guba, 2013).

The social constructivist framework is appropriate to use when seeking to understand the experiences of students in a planetarium setting. Researchers using this framework assume that individuals and groups “develop subjective meanings of their experiences—meanings directed toward certain objects or things” (Creswell, 2013, p. 24). Therefore, using this approach allows the researcher to explore, co-construct, and interpret meaning from the various experiences participants may have in a planetarium.

There are several methodologies that are recommended for use within a social constructivist framework that are consistent with the nature of this study. The most appropriate methodologies for this framework should take a hermeneutic-dialectic approach, where various constructions of meanings by involved parties should be examined and then compared with other situations and meanings (Guba & Lincoln, 2001). Therefore, the types of methods used should first be designed to “delve into the mind” and “uncover the constructions held by the various knowers” (Lincoln & Guba, 2013, p. 40). This is known as the *discovery phase* (Guba & Lincoln, 2001). Creswell (2013) recommends that questions be phrased in broad and general terms in order to allow participants to construct meanings without feeling guided to an anticipated response. The researcher should also use a variety of methodologies including interviews, observations, and participant journals to home in on emergent ideas that arise through consensus (Creswell, 2013). This is known as the *assimilation phase,* where discoveries are incorporated into the contexts of existing constructed knowledge, or where new meanings are constructed from the data (Guba & Lincoln, 2001).

While many methodological options are available to use within a social constructivist paradigm, an important factor to always consider is voice. Social constructivism “fosters the introduction of multiple perspectives to counter the positivist presupposition of a uniform and objective social reality” (Sarbin & Kitsuse, 1994, p. 8). Bakhtin (1993) advocated the use of a variety of voices of both the researchers and participants as an ethical component of research. Because the researcher’s voice plays a part in social constructivist research, it is important for the researcher to maintain a reflective journal throughout the inquiry process (Lincoln & Guba, 2013). Since the role of the researcher is to present the voices of the participants in the story, issues of representation are important to consider (Lincoln & Guba, 2013). The issue of representation is a difficult one to overcome, since the researcher’s “discourse is always partial… and constructs the world from a particular point of view” (Hjelm, 2014, p. 5). While it may not be possible to fully resolve the issue of representation, a number of methods can be used to ensure quality research; dialectical conversations, individual and group member-checking, comparative assessments of participant’s constructions with others, and peer debriefing (Lincoln & Guba, 2013).

Research Approach

This qualitative study utilized a case study approach. Case studies investigate a particular phenomenon in depth (Gall, Gall, & Borg, 2010; Yin, 2009), which in this case involves the experiences of preservice teachers during a planetarium program. Additionally, a case study provides the researcher with an opportunity to take an in-depth look at a specific case within well-defined boundaries established by the researcher (Creswell, 2013). This approach allows the researcher to inquire into phenomena within real-world contexts of the specific boundaries identified by the researcher in a way that "retains the holistic and meaningful characteristics of real-life events" (Yin, 2009, p. 18). Within the context of this research, a case study is appropriate to understand the phenomenon of experience as it applies to the real-world context of preservice teachers participating in a live-interactive planetarium program.

For researchers planning to use a case study approach, several methodological recommendations are relevant to consider. First, a case study provides an in-depth look at a specific phenomenon, and it should be designed to collect a significant amount of data (Gall et al., 2010). In terms of constructing validity, it is important for a case study to include evidence from a variety of sources (Yin, 2009) Data collection methods can range from "interviews, to observations, to documents, to audiovisual materials" (Creswell, 2013, p. 98).

Yin (2009) categories the sources of evidence that can be obtained from these methods as including: documentation, archival records, physical artifacts, interviews, direct observations, and participant observations. After collecting data from the various sources, the researcher can provide a detailed description of the case being studied, and identify emergent themes within the context of the case (Creswell, 2013). Methods used to improve validity in the analysis of the data can include pattern matching, explanation building, addressing rival explanations, and the use of logic models (Yin, 2009).

Researcher Positionality

In qualitative research, it is important to understand the personal biases that influence methodology. There are *etic* biases that influence this qualitative researcher's perspectives in this study, which come from previous personal experiences with space science and as a planetarium educator. This researcher's personal interest in planetariums and space science education come from prior experiences dating back to childhood, when attending space-themed summer camps for multiple years. During those formative years, this researcher developed an appreciation for *life-long learning in an ever-expanding Universe of endless possibilities,* a phrase learned from the researcher's father. That appreciation for science and life-long learning later manifested itself when as an adult this researcher became an amateur astronomer and started a career as a planetarium educator. While teaching programs in the planetarium over the course of many years, this researcher presented live-interactive programs to audiences as well as created a full-dome movie that recreates the experience of a total solar eclipse. Having a background in space science and the planetarium community has led this researcher to wonder about the types of experiences audiences have within the planetarium space. Additionally, during the study, this researcher experienced viewing a total solar eclipse, which led to new perspectives on the use of SIVEs in the planetarium. This perspective is described in further detail in Chapter 6.

Methods

Participants and Recruitment

The study was conducted as part of a science content for elementary teachers course at a private university in the Southwest United States during the fall 2017 semester. This site was selected due to its unique attributes that make it suitable for a case study. First, the focus of the study revolves around earth and space science concepts. This represented a single unit taught within the course. Second, the study explored the experiences of preservice teachers in a portable planetarium. The participants in this study were selected from 19 undergraduate preservice teachers enrolled in the science content course, chosen specifically because they participated in a planetarium program as a requirement for their coursework. The boundaries provided by conducting this study as a part of a science content for elementary teachers course made it a suitable choice for case study research.

All students enrolled in the class were informed of the study and given the opportunity to participate. Students were invited to participate in research involving teaching methods for the semester by a teaching assistant in the College of Education in order to reduce researcher influence. During the first week of class, students were provided with a Human Subjects consent form (Appendix A), and a Media Release (Appendix B). Students who wished to participate in the study were asked to complete and return the consent forms. Students who did not wish to participate in the study were required to complete the planetarium lesson and assignments as a requirement for class; however, it was made clear that participation or lack of participation in no way affected the student's grade or standing in the class.

All 19 preservice teachers who agreed to participate in the study completed a questionnaire (Appendix C). Their responses were analyzed, and a purposive sample of five individuals was selected from the group to provide maximum variation of responses. This limited sample size provided the opportunity to examine the experiences of the participants in depth. Two of the participants indicated they had never been in a planetarium before, while three described previous experiences with planetariums to varying degrees.

The participants were traditional college students in their sophomore year of undergraduate coursework, and ranged in age from 19-22. Each participant was assigned a pseudonym to protect their confidentiality. At the time of the study, Casey was 19-years old, and identified as a Caucasian female. Jennifer was 19-years old, and identified as a Caucasian female. Laura was 22 years-old, and identified as a Caucasian female. Kayla was 20-years old, and identified as a Caucasian female. Tiffany was 19 years-old and identified as an African-

American female. Casey, Jennifer, Laura, and Kayla were early childhood education majors, and Tiffany was a rehabilitation of the deaf major.

Lesson

The lesson in this study was conducted in a portable planetarium. The equipment used consisted of a 5-meter inflatable dome, and a Digitarium Zeta Portable combined computer/projection system that used Nightshade NG software. Nightshade NG was designed as "simulation and visualization software for teaching and exploring astronomy, earth science, and related topics" (Spearman, 2017, para. 1), and it can create a digital representation of the sky from an earth-based perspective that includes celestial objects (e.g. the sun, moon, stars, and planets), constellation imagery, and other tools useful for celestial navigation. Additionally, the software can create the illusion of flying through space with a space-based perspective of the solar system and objects in the galaxy. The Digitarium Zeta system was placed in the center of the dome, and students sat in a concentric configuration.

The provided lesson was a 45-minute, instructor-led, live-interactive planetarium program. The content of the program centered around concepts consistent with NGSS 5-ESS1-2 standards of rotation, revolution, celestial motion, patterns of the sun-earth-moon system, and planets of the solar system (NGSS Lead States, 2013). The students were asked to participate in the lesson using a variety of live-interactive teaching methods such as modeling, kinesthetic activities, dialog, and questions (Small & Plummer, 2010). After the lesson, participants were asked to write a reflective response about their time in the planetarium.

Data Collection

Consistent with a qualitative case study approach using a social constructivist framework, this study utilized multiple sources for data collection, which included: a questionnaire before the planetarium program (Appendix C), video recording of the planetarium lesson, reflection responses to a prompt (Appendix D), interview questions (Appendix E), and a researcher journal.

Questionnaire. Since students' thoughts and action are informed by prior experiences (Dewey, 1958), a brief questionnaire was utilized to collect data on prior participant experiences with astronomy content and planetariums. The questionnaire included open-ended questions to allow for a wide-range of participant response. Three weeks before the planetarium lesson, participants were emailed a link to complete the questionnaire online. An online questionnaire with similar questions was pilot-tested with 16 in-service science teachers during the summer of 2017 (Appendix F).

Video Recording. The purpose of video collection in the planetarium was to record the various types of interactions participants have inside the planetarium. To collect such data in a dark environment, a camera capable of capturing infrared light was used. While there is limited research on using video recording in the planetarium space, educational research has shown that "using video to collect data reveals the multimodal dynamism of classroom interaction" (Flewitt, 2006, p. 29), which can lead to new insights. Two pilot tests were conducted to determine the viability of using an infrared video camera to capture participant interactions in a planetarium, and the equipment used was found to provide sufficient quality for the present study.

Reflection Response. After the planetarium experience, participants were asked to create a reflection response describing their experiences and perceptions. Reflections can foster preservice teacher thinking "about their experiences and their subsequent action based on these experiences" (Clarke, 2004, p. 11). Reflections have also been recommended as a useful form of data collection in astronomy education research (Stroud, Groome, Connolly, & Sheppard, 2006).

The reflection response prompt was pilot-tested with 30 preservice teachers during the spring 2017 semester.

Interview. One week after the lesson, an audio-recorded interview was conducted with participants. The interview followed a semi-structured, open-ended interview protocol (Creswell, 2013) to allow participants to openly discuss and describe their experiences in the planetarium. The interview questions were previously piloted with five preservice teachers during the spring 2017 semester.

Data Analysis

The study utilized a variety of qualitative analysis methods consistent with a case study approach. Creswell (2013) identifies four ways in which to analyze qualitative data from case studies: categorical aggregation, direct interpretation, patterns, and naturalistic generalizations. Within the context of this study, data were analyzed using categorical aggregation, and seeking patterns. Student responses to the questionnaire, interview questions, and reflection prompt were analyzed using categorical aggregation through open, axial, and selective coding to identify emerging themes. In addition, the audio-recorded interviews were transcribed. Video recordings of the planetarium lesson were analyzed using a constant comparative method (Ratcliff, 2003) to represent the various forms of interaction occurring in the planetarium rather than transcribing the event (Flewitt, 2006). While transcription can be a useful method for analyzing audio and visual recordings, transcription alone values aural response rather than the full range of interaction. A constant comparative method involves a form of categorical aggregation, where video segments are initially coded, then categorized, and compared in relation to each other. In analyzing the data, a word table was utilized to identify if there are any "similarities or differences among the cases" (Creswell, 2013, p. 200). To analyze the word table, a software program, Wordle, was used to visually represent the data with a word cloud. Prior research has validated word clouds as a methodology to visualize and validate findings (McNaught & Lam, 2010). To answer the primary research question of "*What are the experiences of preservice teachers who participate in a live-interactive portable planetarium program that uses a simulated immersive visual environment?"* the data were analyzed in the context of the research sub-questions as explained below.

Research sub-question 1. To answer the research question "*In what ways do preservice teachers participate in/ interact with a live-interactive portable planetarium program?*" video data were analyzed using a constant comparative method. In particular, the analysis focused on categorizing the types of interactions of the participants.

Research sub-question 2. To answer the research question "*How do preservice teachers describe their experiences after participating in a live-interactive portable planetarium program?*" participant responses to the interview questions and reflection prompt were analyzed using initial, axial, and selective coding to determine any trends in the data.

Research sub-question 3. To answer the research question "*What connections to outside events or experiences do preservice teachers make after participating in a live-interactive planetarium program?*" participant responses to the interview questions and reflection journal were analyzed individually using a direct interpretation method.

Research sub-question 4. To answer the research question "*In what ways are the experiences of preservice teachers in the planetarium educative, noneducative, or miseducative?*" participant responses were analyzed using categorical aggregation to identify the variety of ways participant experiences could be classified as educative, noneducative, or miseducative, as defined previously in the chapter.

Research Trustworthiness

Several methods were used to strengthen the trustworthiness of the qualitative results of this study. Glesne (2006) provides multiple approaches for qualitative researchers seeking to improve the trustworthiness of their study, which include identifying researcher biases, utilizing multiple sources of data, reviewing interpretation of data with members of the study, and providing rich detail. This researcher has clarified existing biases previously within the chapter. Additionally, the research utilized a variety of data sources including video recordings, participant reflections, interviews, and a researcher reflexive journal as previously described. In keeping with a social constructivist approach, this researcher conducted member-checks with the participants to determine if the interpretations drawn from the data were consistent with how the participants constructed meaning from their experiences. Lastly, the results are presented using rich descriptions to provide context for the findings.

CHAPTER 4. RESULTS

This chapter begins by providing a description of the participants and their responses to the pre-planetarium questionnaire. The descriptions are followed by a narrative account of the planetarium program. Next, analyses of the findings from the data collection are presented in relation to the research sub-questions posited in Chapter 1.

Descriptions of Activities

Questionnaire

Three weeks before attending a lesson in the portable planetarium, and before starting the earth and space science unit of the class, students were asked to complete a questionnaire. The questionnaire asked students to describe their prior experiences with planetariums or what they would expect from a planetarium if they had not been to one before, followed by a question asking them to describe their past experiences with space and astronomy content. An introduction to the participants of this case study and their responses to the questionnaire are presented. Four (Casey, Jennifer, Kayla, and Laura) were sophomore early childhood education majors and one (Tiffany) was a sophomore habilitation of the deaf major.

Casey. Casey described herself as “a pretty talkative person.” When answering the questionnaire, she stated that she had visited a planetarium before. When asked to describe her previous experiences with planetariums, she stated, “It was very educational. I love stars and outer space, so seeing all these models of that was so fun.” Casey described having a personal interest in space and explained: “Personally, I find myself following space accounts on social media and learning about the planets and stars through that.” She also mentioned that space was fascinating to her, and she has a tattoo of a star.

Jennifer. Jennifer sat at a table with Casey during the course and regarded her as a friend. In the pre-planetarium questionnaire, Jennifer indicated that she had not previously visited a planetarium. She explained:

> I would expect it to be dark and you would be able to see what space and the stars look like. I think it would help you see in more detail because it would have proper lighting, also there would be an expert there to help guide you.

When describing her previous connections with space and astronomy, Jennifer focused on a time during an elementary school science unit when she had to choose a planet to study, which included creating a model of the planet and a presentation. She further elaborated, "I loved this activity and it helped me to learn about a planet in more depth."

Kayla. Kayla stated that she had been to planetariums before, describing her previous experience as "very calming but also educational." She also noted that during her prior visit, she was "able to see many things that wouldn't be as visible to the naked eye when looking at the sky from a more polluted area." Kayla described multiple prior connections with space and astronomy. She initially described an astronomy class she took during her senior year in high school where she "got to learn different things in the lecture about specifics in the sky." She further explained that as part of her class she "got to go out to a less populated area once a month and my teacher brought many different telescopes for us to look through and see different specific things that were happening that night." Kayla also elaborated on personal connections to space and astronomy, having watched the *Cosmos* television series. Additionally, she described having a "summer house… in the middle of a redwood forest with no light pollution so we observe the sky often and have gotten to see some very cool things."

Laura. Laura stated that she "had never been to a planetarium before." When asked to describe what she would expect from a planetarium, she stated, "I would expect a realistic view of the night sky and planets. I would also love it if they showed different things in the night sky like the milky way or northern lights." When describing her prior connections to space and astronomy content, Laura focused on personal connections, including career aspirations and her family. She stated, "I grew up wanting to be an astronaut, so I loved reading books about space." However, that personal interest in becoming an astronaut waned after she "found out how much math and science went into it." Laura also described things she learned from her grandfather. She explained in detail:

> My grandfather had a huge telescope and we would try to look at the full moon together when it was visible. My grandfather was a great resource for me when I was young because he was one of the doctors that helped NASA discover ways to keep atronauts' [sic] muscles and bones from deteriorating and getting weak while on the spaceship.

Tiffany. Tiffany, a sophomore habilitation of the deaf major with plans of becoming a deaf education teacher, responded that she had visited a planetarium before. When asked to describe her prior visit, she stated that she "really enjoyed it." She elaborated that "the planetarium was very interactive with the audience and I learned a lot of cool facts about space that I did not know." When asked to describe her prior connections to space and astronomy content, Tiffany reiterated her previous visit to a planetarium, and also described a preservice teacher workshop provided by a local science museum, where she learned "ways to teach elementary students space science through learning the content from Master teachers."

Planetarium Lesson

The planetarium lesson was conducted on a Monday following a holiday break. Students arrived at an on-campus auditorium with stadium-style seating, and on the wooden floor was an inflated portable planetarium. The planetarium dome was navy blue, five meters in diameter, and three meters tall. Prior to entering the planetarium, students sat in the auditorium chairs. As the instructor for the class, this researcher introduced students to the planetarium by informing them about the technology used and how to safely enter the dome.

The students then entered the planetarium in a single-file line through a zipper door. When they entered, students saw a darkened room with imagery of a forest setting being projected on the dome screen, with the computer and projector system on the floor in the middle of the structure. The change from being in a brightly lit auditorium to a darkened planetarium elicited audible gasps and “wows” from students upon entering. As students entered, they made a circle around the outer edges of the inflatable dome, and sat in a concentric seating pattern on the floor.

Once all the students were seated on the floor, the instructor asked them to look around the planetarium and make observations about what they could see. Tiffany answered that she could see the computer and projector in the middle of the planetarium. The instructor also asked what could be observed on the planetarium screen. The view projected onto the dome included a daytime forest setting with trees, a blue sky, and visible sun. In addition, the cardinal directions were projected on the screen, as well as a clock with the current date and time. Objects identified by the students included trees, cardinal directions, and the sun. During this time, the instructor asked a series of questions about what the students could observe in the sky. These questions related to such concepts as the brightness of the sun, its close proximity to the earth, and how light from the sun interacts with the atmosphere.

Once students were oriented to the planetarium, the instructor directed their attention to the time display. Using a touchscreen tablet, known as the Universal Console, the instructor virtually increased the speed of time of the simulated sky. Students were asked to make observations about what appeared to be happening. Several in the class responded, “The sun is moving." When queried for more information about if the sun was actually moving in the sky, other students responded that the earth was rotating. Casey added that the earth is spinning on its axis.

To further demonstrate the concept of objects appearing to move as the earth rotates, the instructor used different kinesthetic activities. First, the instructor asked Casey to stand up as a part of a demonstration to model the rotation of the earth. During the demonstration, Casey was asked to pretend to be the earth, with her nose representing the university, and the light from the projector representing the sun. The instructor began the demonstration by asking Casey to rotate counterclockwise. As she was rotating, the instructor asked the other students questions about what time of day it would be at the university (Casey's nose), and where it looked like the sun was in relation to Casey's nose. The instructor then asked the students another series of questions:

> Instructor: Did the sun move at all?
> Class response: No
> Instructor: So what was moving?
> Casey: I was
> ….
> Instructor: What do you think it would look like for those standing on the earth?
> Class response: The sun is moving

After this demonstration, the instructor asked all students to participate in a similar demonstration. The students were asked to extend their arm and hold their thumb out in front of them, pretending their thumb was the sun and their face was the earth. Next, the students were instructed to slowly turn their head to the left, and notice what side of their face their thumb looked like it was moving. Several students responded that it looked like their thumb moved to the right side of their face. The instructor reinforced that this same effect is why objects such as the sun and stars look like they are moving in the sky while the earth is rotating. Students were then asked how long it takes the earth to make one rotation, to which several students replied, “24 hours.”

Next, the concept of earth revolving around the sun was discussed. The instructor asked a series of questions about how the earth revolves around the sun, and how long it takes to do so. In addition, the instructor modeled the process of earth’s revolution around the sun by walking in a circle around the outer circle of the planetarium.

As time continued to move forward within the planetarium, the sun’s position changed in the sky and the moon became visible, which allowed the instructor to transition into a discussion about the moon. With the visual projection of a setting sun and the moon visible at the top of the dome, students were asked to describe what the moon looked like, to which one student responded, “a half circle.” The instructor informed the students that this phase is known as a first quarter moon. Students were then asked to make a prediction about how the moon might look at the same time on the following night, and point to where in the sky they thought the moon would be. After the students made their predictions, the instructor used the Universal Console to change the date in the planetarium. When the instructor did so, several students released audible gasps, “wows,” and laughter. Students were then asked to identify what happened to the moon. This activity of predicting where the moon might be and what it might look like on subsequent nights continued for three more times.

After students were introduced to the pattern of change in the moon, the instructor went to a zoomed-in view of the moon, so that it was the only object viewable on the dome screen. The instructor then proceeded to show the appearance of the moon throughout its different phases: new moon, waxing crescent, first quarter, waxing gibbous, full moon, waning gibbous, and last quarter. After going through the different phases, the instructor pointed out to the audience from the date and time display that approximately one month had passed, which is how long it takes for the moon to go through all its phases.

Next, the simulated image returned to an earth-based view of the evening sky, which slowly transitioned into the night sky with views of stars and the Milky Way. During this portion of the lesson, the instructor discussed concepts related to constellations, showing visual representations of constellation art, using constellations as a map of the night sky, and how to identify the North Star. The instructor also explained how a person could use the North Star as a guide to know to determine how far north of the equator he or she is. To demonstrate this technique, the instructor first showed the students how to find the North Star, then asked them to hold their fists out to the horizon and continue stacking their fists on top of each other until they lined up with the North Star. The students had to stack up three fists to reach the correct height in the sky. In this demonstration, the instructor explained that the height of each fist represented 10 degrees north of the equator, and the location of the university is approximately 30 degrees north of the equator. Next, the instructor asked students to predict where they thought the North Star might be when traveling north to locations such as Chicago, Canada, and the North Pole. After students made their predictions the instructor used the software to simulate traveling to a different location so the students could see the how the North Star moved higher in to the sky as they traveled farther north. As the instructor was discussing these concepts, Casey began talking to Jennifer, and pointing at something in the planetarium. Jennifer also held her hand out, making an L-shape with her fingers.

After discussing constellations, the instructor informed the students that they would be simulating leaving earth and traveling to space. As the simulated visuals gave the appearance of rising above the earth, the instructor pointed out the city lights of the surrounding local, state and country regions. Next, the moon as seen from space became visible. The instructor used the software to turn on a blue line representing the orbital path the moon makes around the earth. From this perspective, the instructor reiterated the concept of the phases of the moon as it travels around the earth.

While observing the moon from space, the instructor introduced the concept of eclipses by asking students if they remember what occurred a few months prior to the lesson, to which several students replied, “The solar eclipse.” Using the software, the instructor then displayed shadow lines of the moon and earth. Putting the moon into motion as it orbited the earth illustrated how occasionally the shadows line up, causing an eclipse. The instructor explained to the students that when the moon casts its shadow on the earth it is called a solar eclipse, and when the earth casts a shadow on the moon it is called a lunar eclipse. At this point, several media clips were displayed on the screen that showed both earth-based and space-based views of a lunar eclipse followed by a solar eclipse.

Next, the view in the planetarium transitioned to display the planets in the solar system with their respective orbital lines around the sun being displayed. While the visuals in the planetarium were changing to provide a space-based view of the solar system, the instructor asked if anyone knew how many planets there are in the solar system. This portion of the lesson included questions about the number of planets in the solar system, a discussion of why Pluto is no longer considered a planet, and a review of the planets in the solar system. As time was running short in the planetarium, the instructor asked the students which planet they would like to visit for a closer look. The majority of students said they would like to see Jupiter up close. The instructor then zoomed-in to the planet, which provided students with a detailed view of the Jovian system and its moons. While looking at the planet, the instructor discussed several features of Jupiter such as its size, its composition as a gas-giant, the Great Red Spot, and the over 60 moons that orbit it.

The tour concluded with a view of the galaxy. The images zoomed out from the solar system so that the sun appeared to be just another star among a multitude of other stars. As the images continued to zoom out, eventually the view changed to display the Milky Way galaxy. While viewing the galaxy, the instructor explained that the galaxy is a collection of billions of stars with a massive black hole in the center. The instructor asked if any students could explain why the Milky Way appears to be a band across the sky, but no students responded. To explain the concept, the instructor asked the students to make a circle with their two hands to represent the Milky Way. Next, the students were asked to turn their circle on its side so they could only see the edge of the circle. Then, they were asked to imagine they were inside the circle looking at all the stars from the inside. While doing this demonstration, the instructor transitioned from outside the Milky Way zoom back towards earth, and during that process the image of the Milky Way band became visible as it stretched across the planetarium.

While zooming back to earth, the instructor concluded the planetarium lesson by asking if students had any questions about anything that was or wasn’t covered in the planetarium but they would like to know more about. The students asked no questions at that time. The instructor then returned the planetarium to the initial earth-based view of the forest setting. The students were instructed to stand up, stretch their legs, and exit the planetarium in a single-file line, the same way they came in.

Research Questions

After participating in the planetarium lesson, the students completed a reflection prompt regarding their time in the planetarium. One week after the planetarium lesson, the participants of the case study were asked to take part in an interview with questions related to the four research sub-questions of this study. The recorded video of the planetarium lesson along with participant responses to the reflection prompt and interview question are used to address each of the research sub-questions

Research Sub-Question 1: In what ways do preservice teachers participate in/ interact with a live-interactive portable planetarium program?

The planetarium lesson included a variety of elements in which the preservice teachers participated. These elements included *questioning*, *kinesthetic activity, observation, making predictions, choosing the focus of content*, and *social interactions between peers*. Each element is described in detail in the following sections.

Questioning. One of the first methods of interaction for students in the planetarium was questioning. To orient students to the new setting, the instructor began by asking a series of questions. One such set of questions from the first few minutes in the planetarium involved identifying the sun as a star.

> Instructor: Can we see any stars right now?
> Several students: No.
> Jennifer: Well, the sun.
> Instructor: Is the sun a star?
> Several students: Yes.
> ….
> Instructor: So the sun is the only star we can see in the daytime. Are there any other stars in the sky during the time?
> Several students: Yes.
> Instructor: Where are they?
> Jennifer: They are too far away.
> Instructors: Ok, so you say they are too far away. Any other ideas why we can't see other stars in the daytime?
> Casey: It needs to be darker.

This interaction included multiple types of questions and student responses. First, the instructor asked yes-or-no questions, such as "Can we see any stars right now?" and "Is the sun a star?" Such questions elicited responses from multiple students in the planetarium. In addition, the instructor asked questions that required students to think of possible explanations, such as a reason for why other stars can't be seen in the daytime. These types of questions elicited fewer responses from students; however, individual students did provide answers to the questions.

In other instances, the instructor asked questions that required students to think of an explanation for a phenomenon. For example, he asked students to explain the blue color of the sky in the daytime. Jennifer responded by saying, "The reflection of the water." When the instructor asked if the students could think of any other ideas or explanations, the class remained silent. Other instances of explanation questions involved the rotation of the earth, observations of the moon, and the structure of the galaxy. These topics were also connected to other methods of inquiry and are discussed in further detail in later sections.

Recall questions were also utilized in the planetarium. One example of a series of recall questions occurred while the instructor and students discussed the concept of rotation and revolution.

> Instructor: How long does it take for the earth to rotate one time?
> Laura: 24 hours.
> Instructor: Very good. It takes the earth 24 hours to rotate one time, and we simply call that one…?
> Several students: Day.
> ….
> Instructor: The earth makes another type of motion around the sun. Does anyone know what that is called?
> Casey: An ellipse.
> Instructor: Okay. That is the shape of the path… the earth doesn't orbit the sun in a perfect circle… What is that movement called?
> Kayla: Rev… revolution?

The instructor used these questions to assess student understanding and recall of concepts discussed during the lesson. Recall questions were also used when discussing the phases of the moon. While showing visuals of different moon phases, the instructor asked questions, such as "Does anybody know what this phase of the moon is called?"

The instructor also asked observation questions. With these types of questions, the instructor asked the students to describe what they saw happening inside the planetarium. These such questions were regarding the rotation of the earth, apparent motion of objects in the sky, and phases of the moon. The types of observations students were asked to make are covered in detail in a later section.

In addition to the instructor asking questions, students were given the opportunity to ask questions. During the final segment of the lesson, the instructor asked the students if they had any questions about what was covered or if they were curious about anything else. Students had the opportunity to ask additional questions, but no one in the class asked anything further.

During interviews after the planetarium lesson, two participants identified questions as one way they interacted in the planetarium. When asked in what ways she interacted in the planetarium, Tiffany stated, "Yeah, when you asked us simple questions or like what time it is." Tiffany later went on to explain how she felt about the questions, saying, "I'm more of a person who doesn't like to speak much, but you know I do think about what you asked and I do think, you know I think in my head for sure." For Tiffany, even though she recognized that she may not have answered many questions, they did prompt her to think about what was asked.

Kayla also identified questions as one way she interacted with the planetarium, as she explained:

> There were a lot of interactive questions you asked… You prompted a lot of discussion within the planetarium. So you would show something, ask what we saw, ask if we knew something about it, and stuff like that; which I thought was really great 'cause it kept everyone engaged the whole time.

In this description, Kayla specifically mentioned interacting with the planetarium lesson by being asked questions about what was observed in the planetarium as well as recall questions. She added that this form of interaction was a way to keep the students engaged during the lesson. Kayla later explained how she felt about the questions and how the instructor structured them that might promote student engagement by stating:

> I mean some people are more willing to answer than not, but I think it was all stuff that most people were able to answer. It wasn't like questions that were beyond our knowledge or something like that. So you didn't feel like you didn't want to say something, thinking you were wrong, or at least that's how I felt. I felt like I could answer the questions.

For Kayla, the questions in the planetarium were asked by the instructor at a level she felt comfortable answering.

Kinesthetic. The students also participated in several kinesthetic activities in the planetarium. The first interactive activity involved modeling the rotation of the earth. Casey was asked to stand to be a facsimile of the earth, with the light from the projector shining on her representing the light from the sun. Casey was asked to turn slowly to illustrate how the light from the sun hits different parts of the earth as it rotates. During this activity, Casey and the students were asked questions about the time of day it would be at different points during the rotation period, and where it looked like the sun might be in the sky.

Two participants talked about the rotation demonstration during their interviews when asked about ways they interacted in the planetarium. First, Casey described what participating in that activity was like for her by saying:

> I was pretending to be the earth. I was rotating in front of the projector, which was the sun. That was cool for me because I like to present stuff. That's just the type of person that I am. I was very comfortable standing up and rotating as if I was the earth to see how the sun casts light on the earth. It was unique to be able to have a human model representation of the planets I guess. I think that when I would look around the room that

> students were responding well to having a different visual of how light is projected and how the earth revolves and rotates and stuff. I think it was a good example.

In this description, Casey explained how she felt about being asked to stand in the planetarium while her classmates remain seated. She stated that because of her personality, she was comfortable participating in the activity. She also stated that she felt the model was a good example for teaching the concept of earth's rotation, and that it appeared to her as if others in the class were "responding well" to the illustration.

When Jennifer was asked to describe the presentation of content, she focused much of her comments on the rotation activity during her interview. She stated:

> It was when the sun was shining on her. Then it was like this time of day, that time of day, which was cool 'cause we had looked at it in class or in the planetarium, so then you could see it in real life.

Jennifer was then asked to expand upon what she meant by her phrase "in real life." She went on to say, "You could see the light on her face, and then see her turn….and so since it was so dark in there, you could really see it, which for me helped. Like, I was able to understand it better." For Jennifer, having a physical representation of the contrasting light from projector with the darkness in the planetarium allowed her to visualize the concept of earth's rotation. In her concluding remarks about this activity, Jennifer noted that she "could see kids really wanting to do that."

The planetarium lesson also included another kinesthetic activity related to rotation. After Casey sat down at the end of her demonstration, students were asked to hold out their thumb to represent the sun and slowly rotate their head to represent the rotation of the earth. The purpose of this kinesthetic activity was to allow students to visualize the apparent motion of an object because of rotation. Unlike the first example, in which only a single student could kinesthetically participate, this demonstration allowed every student to create a visual model.

Both Tiffany and Kayla talked about the thumb activity in their interviews. When asked in what ways she participated in the planetarium, Tiffany mentioned, “When you did the put your thumb out example. I felt that was really good and that was something like okay I can use that with my students in the future if they're confused.” When asked to further elaborate on what she did, Tiffany could not recall in detail. She attempted to explain by saying, “I think you were trying to explain to us about if the moon's over here, then the sun, I forgot what you were really trying to explain.” Neither Tiffany nor Kayla could remember the full details of the activity. Kayla said, “I don't remember exactly what we were doing with the thumb. But…that was another good thing that we did with interacting. Actually getting your, like body involved in it.” While Kayla did not remember the concept tied to the activity, she was able to recall the event. Additionally, when asked to elaborate on her explanation of “good thing,” she stated:

> I thought that was another good way of interacting because, I'm in a geology class right now too and we actually ... This is one of the things that we do for our test, like one of the things that we can remember. As like, this is how the planets rotate or something if we do this [holding thumb out, moving finger from other hand around thumb], and so, I guess those two kind of can tie together in a way.

In this explanation Kayla connected a kinesthetic activity that occurred in the planetarium to another movement-based model she learned in a geology class. Even though the motion of the thumb-model from geology class differs from what was done in the planetarium, she found a similarity between the two.

The next kinesthetic activity students participated in related to the North Star. After identifying the location of the North Star, the instructor explained that it could be used for navigation and knowing how far north from the equator a person is. To illustrate this concept, the instructor asked students to hold out their fist to the horizon, and continue stacking their fists on top of each other until they reached the height of the North Star, which was approximately three fists. The instructor explained that each fist represents 10 degrees north of the equator, and from the location of the planetarium it was about 30 degrees north. While all the participants can be observed making these motions on the video recording, none of them discussed the activity during the interview as a way in which they interacted with the planetarium lesson.

The final way participants interacted during the planetarium lesson occurred when discussing the Milky Way galaxy. To demonstrate the discrepancy between the appearance of our galaxy as a spiral galaxy and the band of the galaxy that can be seen at night, the instructor guided the participants in making another model with their hands. In this activity, students were asked to make a circle with their hands to represent the Milky Way. When looked at from one direction, the whole circle is visible, but when looked at from the edge all that can be seen is a line. This activity was discussed by one participant, Laura, who explained that the activity helped her “visualize how from our perspective if we ever see in the sky like the Milky Way, it looks like a straight line… 'cause we're on the inside of it.”

Observation. Another way participants interacted in the planetarium was by making observations. Students were first introduced to making observations at the start of the lesson, when the instructor asked them to identify what they saw in the planetarium. Tiffany offered the first observation by identifying the computer and projector used in the planetarium. Kayla identified the trees being projected on the planetarium screen. Casey identified the cardinal directions. She also noticed a distinct black line at the bottom of the projection and asked for clarification about the location being represented, saying, “Is it in water?” The instructor explained that the line marked the point where the projection stopped. Finally, during this portion of the lesson Jennifer identified the sun being displayed in the sky.

Students were also asked at various points in the lesson to make observations about what was occurring in the planetarium. One interaction involved introducing the concept of rotation and celestial motion. While speeding up time in the planetarium, the instructor asked the students what they observed happening. Several students responded that it looked like the sun was moving. This simulated speeding up of time was used to allow students to quickly make observations of changes in the sky over a period of several hours.

Another time students were asked to make observations was when recognizing changes to the moon over the course of several nights. Similar to how time was sped in to illustrate rotation of the earth, the planetarium software was used to illustrate the location and phase of the moon on different nights. Participants were asked to identify the changes they observed in the moon as it transitioned from a first quarter moon to a full moon. Several students responded, "It is getting fuller," and "It moved east." As the instructor continued to show the phases of the moon, students were asked to observe how long it took for the moon to move through all its phases by looking at the time display in the planetarium, and a student replied, "One month."

During follow-up interviews several students mentioned making observations in the planetarium. Jennifer discussed her thoughts about observing the changes in the moon. She explained:

> I thought [looking at the moon move] was really cool. Then like one after the other, and it was the days. I thought that was cool, 'cause I caught something when you're in, like just in normal days and it's nighttime and the moon doesn't necessarily look like it's moving. You don't pay attention to it, so I thought that was cool.

For Jennifer, being able to observe the changes that the moon makes over a period of several days was interesting. As she explained, part of what she found appealing about the observations was was that she notice something she had not paid attention to before. Casey talked about a similar concept during her interview when she stated she enjoyed being "able to shift around and see all of the different aspects of the stars and I know you zoomed in on the sun and to see the movement of the moon." She further explained that "to be able to see what the actual patterns are in actual day-to-day life in a more sped up motion is super unique to see the actual placement." Similar to Jennifer, Casey found the ability to observe changes and movements in the stars and moon over a period of time as something unique about the planetarium.

Kayla also discussed the role of observations in the planetarium. During her interview, she stated:

> We got to see, like if we were out somewhere away from all of the light of like the city what our actual sky would look like on the day that we were there, which was really cool. And then the time lapse of it transferring into night, so we got to see like the sun setting and, like the moon moving across the sky. And then all the stars coming out, I thought that was a really cool moment, when like it all of a sudden got dark and all the stars showed up everyone in there was kinda like 'whoa' you know, like seeing all of that.

Kayla described multiple observations, including the time lapse, seeing the motion of the sun and moon, and the transition from day to night when the stars began to appear. She also mentioned being impressed by observing the stars in the planetarium.

Making predictions. Participants also interacted with the planetarium lesson by making predictions. This form of interactivity combined other forms of interactivity, including questions, observations, and kinesthetic participation. The participants made predictions in the planetarium during two portions of the lesson: the segments on moon phases, and identifying the North Star.

While observing the moon, students were asked to make a prediction about what the moon might look like on the following night.

> Instructor: I want you to predict where you think the moon is going to be at this time tomorrow night. Right now it's 6:33 p.m. Where do you think the moon might be at 6:33 tomorrow? So right now I want everyone to point where in the sky tomorrow night.
>
> Students: [pointing at various locations in the planetarium].
>
> Instructor: Does everyone have their predictions? Okay, we're going to skip ahead to tomorrow. One, two, three, tomorrow [instructor changes the date in the planetarium].

Students: [gasps, laughter].
Instructor: So… what happened?
Students: It's getting fuller, it moved east.

After making their first prediction and observation, students were asked to repeat this process on three more occasions. Students were asked to evaluate their predictions by checking how close their answers were to where the moon actually was on the different nights. In their interviews, Jennifer, Casey, and Kayla, mention having observed changes in the moon's pattern, but none of them specifically discusses making predictions about the moon.

Students were also asked to make a prediction regarding the North Star. After the instructor finished introducing the concept of the North Star being used to identify how far north of the equator a person is, students were asked to predict where they thought the North Star might be located in the sky at different locations including Chicago, Canada, and the North Pole. For each location, the students pointed to the position in the sky where they thought the North Star would be located, and then the instructor displayed the change so students could evaluate their prediction. While students did participate in this activity, none of the respondents in their interviews or reflections mentioned making predictions about the location of the North Star in the planetarium.

Choosing content. During one segment of the planetarium lesson, students were also asked to choose what they wanted to discuss further. As part of the discussion about planets of the solar system, the instructor gave students the option to visit a planet of their choice. Several students expressed that they wished to visit Jupiter, and no other suggestions were offered. As a result, the instructor used the software to bring up images of the planet, and talked about several features of the planet. This method of participation was not discussed by participants in their interviews or reflections.

Social communication between peers. Finally, participants interacted in the planetarium through verbal and nonverbal social communications with one another. Analysis of the video recording showed that Casey and Jennifer were talking to each other at several points during the lesson. These discussions occurred during the introduction, as well as while discussing the moon phases and constellations. During Casey's interview she confirmed interacting with Jennifer by saying:

> I was talking to the girl next to me a lot. We were talking actually completely about the planetarium, which is unlike me. I sometimes get off task a lot. Just being able to talk with another student who is experiencing something so cool like the portable planetarium for the first time was unique because we were able to share what we were thinking like, "Oh, that's so cool" or, "I never thought this." That was unique.

For Casey, her social interactions with her peer were a way to share her experience with someone else as opposed to what she described as "off task" behavior.

Jennifer also described her social communications with Casey. When asked to discuss ways that she interacted in the planetarium, Jennifer's first response was to state: "I mean, sitting next to Casey. We're friends, and so we were able to be like, 'Oh, that's so cool!' together. Whereas had she not probably been my friend, I would've been like, more quiet." Similar to Casey's response, Jennifer mentioned having a shared experience with a peer as being a way she interacted with the planetarium lesson.

During the discussion of constellations, Casey and Jennifer could be seen in the video recording making different types of hand motions. In one instance, Casey was pointing at an object in the planetarium. When Casey was asked to elaborate on what she was doing she stated:

> I think we were talking about the North Star actually. I think I was showing Haley, who was sitting next to me, something that honestly I think I was talking about a story at my grandparent's house. I think I previously mentioned it to her in a different class. Something where I had used the North Star. I identified it as you need to use it to go north. I think I was like, "That is the North Star." I know that before you were able to

> click something on the remote that named them all. I think that I was trying to prove to her that I knew it was the North Star before you put all the names on the screen.

In this instance, Casey described using verbal and nonverbal communication methods to share knowledge with another student, and relate her past experiences with the content being discussed in the planetarium.

Shortly thereafter, Jennifer can be seen holding her hand out in front of her, making an L-shape. She explained, “I was holding my hands out in an L-shape, and like diagonally towards the constellation.” When asked to elaborate, Jennifer stated, “it was in *Moana*, where she does that… and so she's trying to sail at the stars.” In this instance Jennifer is sharing a connection between the content and a movie with her friend. Both examples represent a social way to interact with the planetarium in a way that was connected to the lesson, but not expressly directed by the instructor.

Research Sub-Question 2: How do preservice teachers describe their experiences after participating in a live-interactive portable planetarium program?

After analyzing the participants’ reflection responses and interview transcripts, several themes emerged from the data about how preservice teachers describe their experiences in a planetarium program. The themes included *novelty, technology, visuals,* and *physical space.* After these themes were identified, words from participant interviews and reflections that were associated with each theme were collected, and a word cloud (Figure 1) was created to visualize the most salient themes discussed. The word cloud provides a visualization of the words and phrases that appear most frequently in participant responses. The most prominent words in the word cloud are connected to the themes of novelty and visualizations. Each theme is discussed in relation to the research question in the subsequent sections below.

Figure 1. *Word cloud of participant descriptions of the planetarium lesson from their reflections and interview responses*

Novelty. One of the first themes to emerge from participant responses was the novelty of the planetarium experience. When initially asked to describe their experiences, each participant used a variety of words to express positive reactions or excitement. These included words such as “unique,” “cool,” “fun,” “awesome,” “interesting,” and “impressive.” When asked to expand on their initial comments, participants often tied these feelings to the novelty of the planetarium in various capacities.

Multiple times throughout her interview, Casey mentioned the uniqueness of the planetarium, and said it “was just super unique for me and the other students in the class to see. I really liked it.” When asked to elaborate on what was unique about the planetarium Casey discussed several factors including the visualizations, the social aspect, and the way she interacted with the planetarium. These aspects are discussed in further detail in the following sections.

Kayla's comments around the experience involved never having been in a portable planetarium before. She explained:

> I mean it was really interesting…. I've never done anything like that before. I've never seen the portable planetarium. I've been to one of the big ones in like a museum, so I didn't really know what to expect about a little portable one, but it was a lot more advanced than I was expecting it to be for it to be portable. Like you were able to do so many different things and you were able to see so many different things that I wasn't expecting to be able to see.

Kayla described not knowing what to expect in a portable planetarium. She said she had visited a planetarium at a museum before, and the advanced state of the portable planetarium system surprised her. She added that she was initially expecting it "to just be a projection of the stars in the sky," but she was impressed by the number of different things she could see. She echoed this statement in her reflection response by writing, "I didn't know what to expect and I was shocked by the amount of things possible."

Jennifer talked about the novelty of the planetarium as a classroom. In her description, she mentioned the feeling of excitement that students might have at seeing the planetarium and having a "learning experience" outside of the normal classroom. She expressed this concept during her interview:

> I think it's like cool to have a class not in your classroom. But then, how you can turn it into a learning experience, especially if it's a portable one, like you wouldn't even necessarily have to leave your school. And so I think they'd be really excited about it, and you could even not tell them. But you know then they see it and be really excited.

Like Jennifer, Tiffany talked about the idea of using the planetarium as a novel experience for students. She explained:

> I thought it was pretty cool, honestly…. One thing that my professor said, deaf children need to experience it to remember it. I think when you have the Live-Time going and you like fast forward time. I think that would be so great [for students] to be like, 'Oh my god, wow. Like at 8:00, this is this or I can still see the moon at 4:00' I just thought that was just really cool.

For Tiffany, a large part of the novelty came from the ability to see changes in the sky and make observations. She also discussed how that excitement in seeing and experiencing those visuals in the planetarium would be a memorable event for students.

In her reflection response, Laura discussed the novelty of the planetarium, writing, "The concept of a planetarium blows my mind!... Its versatility was very impressive." When she went on to state what she found impressive, Laura described the planetarium technology and visualizations, which are discussed in more detail in the following sections.

Technology. The technology used in the planetarium was another theme that emerged from how several participants described their experiences. Laura, Kayla, and Tiffany each mentioned the technology aspect of their experience in both their reflections and interviews, while Casey discussed it solely during her interview. The statements from participants focused on their reactions to the technology, and the visual representations created using the computer system.

One commonality among the statements made by participants was their amazement at the technology. In her reflection response, Laura wrote: "It blows my mind! It's crazy how detailed and accurate a computer can replicate space. I had no idea it could show so many different things." Kayla also wrote a similar statement in her reflection: "I was shocked by the amount of things possible with the planetariums technology." She further explained in her interview that "it was a lot more advanced than I was expecting it to be for it to be portable. You were able to do…and see so many different things that I wasn't expecting to be able to see." Casey also discussed being impressed with the technology during her interview when she stated that it "was super unique and super cool to be able to have such advanced technology… for me and the other students in the class to see."

When the participants elaborated on their views about the technology used, they focused their comments on what the software in the planetarium system could show. Laura stated in her interview, “I didn't realize planetariums had so many different settings and everything that you could show… How you could go to different planets, or I didn't realize that you could speed up the day like real-time picture.” Casey provided a similar statement in her interview when she stated how she was impressed by the technology’s ability to “zoom in on planets and stars and just to be able to fast-forward, go backwards in time.” The ability to manipulate time in the planetarium was also discussed by Tiffany. She stated in her interview that it “was neat… [to be] able to fast forward the live time to show us how the stars, sun, and moon moves.” Finally, Kayla talked about several other features in addition to the changes in time, which she explained in her interview response:

> I was kinda just expecting to just be a projection of the stars in the sky or something but then you were able to like, attach it with the constellations and do a time lapse of seeing all of it.... You could even play the video that you took, like project that up there. And then we could see day time, night time, the actual moon moving and all of just different stuff that I wasn't expecting to be able to do.

For these participants, the visual effects created using the planetarium software were worth discussing when describing their experiences in the planetarium.

Visuals. Another major themed that emerged from participant reflections and interviews involved the visualizations presented in the planetarium. As the word cloud (Figure 1) illustrates, participants frequently mentioned the visuals, and talked in detail about their connections to the visual presentation. The two subthemes that emerged from participant descriptions were related to making observations and the realism of the images.

Observations. When describing discussing the visual presentation in the planetarium, participants talked about several types of observations. These observations included constellations and the planets. Additionally, Cassey, Tiffany, and Kayla discussed making observations about the motions of celestial objects such as the sun and moon in relation to the time lapse used in the planetarium.

The concept of observing constellations was first mentioned by three participants in their reflection responses. Jennifer wrote that her "favorite part was the view of all the constellations. It was cool and very pretty." Tiffany also wrote in her reflection that she "thought it was cool to see the different types of constellations such as Ursa Minor." Kayla also reflected on observing constellations by writing, "I thought it was so interesting being able to see what our sky where we are looks like." She further elaborated in her response that "putting the constellations on top of the stars gave me a much better image of all of them because I am not able to find the constellations on my own when looking at the sky."

In addition to their written responses, participants discussed observing stars and constellations during their interviews. Jennifer elaborated that the reason looking at the constellations was her favorite part of the program was because "it felt like I was in the country by my house, looking at the stars." Tiffany discussed the educational value of her observations, as she explained:

> I thought the Live-Time was just a great way to teach us and we can see a visual versus just showing pictures. It was just great for us to see it live, where we're from. Like… you could see this constellation here if you go outside during this time.

For Tiffany, the ability to see the locations of constellations at certain times was useful to her. Kayla also elaborated on the educational value of observing constellations. During her interview, she stated:

> I took astronomy in high school so I already could, like, I knew a lot about the sky and stuff like that, but I've never been able to like look at the sky and pick out the constellations or something like that. So being able to see the actual image of what was going on, like that night for us, and then you could put up like just the lines that made the constellation, and then like an actual picture that kind of showed the story about it. I thought that was super interesting and I wasn't expecting to be able to see that, and so

> stuff like that, like I can't really pick out in the night sky if I just look on my own, so it was really cool being able to see it just in the Planetarium.

For Kayla, seeing the constellation lines and their artistic representations was useful to her in identifying what she was observing.

In addition to constellations, several participants described observing planets during the planetarium lesson. During the lesson, the instructor displayed images of the entire solar system, but only close up views of a single planet, Jupiter. In Tiffany's reflection, she wrote, "I was looking forward to exploring more of the planets however since we were on a time restriction we did not have time, but I would love to see that in the future." Tiffany reiterated her feelings about seeing the planets during her interview when she stated, "The planet part was probably definitely my favorite part of the planetarium, to see and learn about the different planets." Laura also discussed the visualizations of looking at the visualizations of the planets from a solar system view. In her interview, she stated:

> I thought it was interesting, because it showed the little simulation of what it would be like to travel to a different planet type of thing, or how you could see the orbits getting warped with the different positions that you were in.

Additionally, participants discussed observing changes in celestial objects, such as the sun and moon, as a result of the time manipulation in the planetarium. In her reflection, Kayla wrote, "I thought it was so interesting being able to see what our sky where we are looks like and getting to see the time lapse of it becoming night and where all of the stars are." Casey also discussed her feelings about her observations in the planetarium with the increased flow of time:

> to see the movement of the moon, that's just something that you're not able to see in everyday life because time moves so slow. To be able to see what the actual patterns are in actual day to day life in a more sped up motion is super unique to see the actual placement.

Similarly, Laura discussed these types of observations, and in her description explained their usefulness for learning:

> I thought it was fun and in that I could visualize, maybe better, some of the concepts that we covered in class... Like when we were talking about how the moon moved across the sky. It was a lot easier to visualize that in the Planetarium than on the slide and the PowerPoint.

For Laura, the increased speed of time allowed her to visualize the concept of objects moving across the sky better than in class descriptions and flat PowerPoint images.

Realism. In addition to the types of observations made, participants also provided comments about the quality of the visual presentation in the planetarium. The descriptions of three participants centered on the realistic nature of the images. Two of the participants also felt as if the visuals had a three-dimensional appearance. Additionally, two participants described feelings of being in the setting being simulated.

Casey, Kayla, and Jennifer each made comments during their interviews regarding feeling as if the presented visuals were realistic. Casey stated, “To be able to have something as close to realistic as we can get here on earth and as college students was super unique and super cool,” and later added, “I really just overall really liked observing the realistic visuals.” Casey elaborated on why she felt the images looked realistic by saying, “Specifically the dome shape of the planetarium gives that realistic view because you have that 360 view of what the sky would look like in a perfect non-polluted sense.” While Casey described the planetarium creating a close representation to realistic visuals, Kayla felt as if some of the images were actual live images rather than the computer-generated images that they were. In her interview, she stated, “It was really real-looking. Like it didn't ... I mean a lot of it was like the live picture stuff so I guess it should look real.” She then described additional images that she knew weren’t live, and explained that they didn’t look “super animated, even the time lapse of things that haven't even happened yet actually still looked completely realistic, and what you would actually see if you could go somewhere that didn't have so much light pollution.” Jennifer also discussed the realistic appearance of the images, in connection with her experiences of growing up in a rural area. During her interview she explained:

> Like I'll drive and just look at the stars. So then when I saw it in the planetarium, I guess maybe I would have expected not, for it not to look as real. But when I think it was one scene where it was like, you looked at just the stars and constellations, and that was like super real to me. And so it is not what I expected. I would have expected it to not look as real, since I've seen it in reality.

The realistic appearance of the stars surprised Jennifer because of her previous experiences of observing stars at home.

In addition to describing the visual representations as realistic, Jennifer and Casey as made mention of the images appearing to have an almost three-dimensional effect. Jennifer stated during her interview, “I don't know if it was 3D, but it felt like it was. Like when you were like, it's gonna feel like we're moving. Sometimes that's how I felt.” Casey also discussed the images in the planetarium in comparison to other flat images shown in school. She explained that she felt as if “a lot of times in school and growing up you see not cartoon images but flat images. Not that this was something that we could touch and that was tangible but it really gave more of a 3D look.”

Finally, Laura and Jennifer discussed feelings of being in the environment represented in the planetarium. In her reflection, Laura discussed previous aspirations of being an astronaut as a kid, and added, “Although I couldn’t experience 0 gravity, I got to see what it looked like to travel in space.” In her interview, she further elaborated on the planetarium lesson by saying:

> I thought it was interesting, because it showed the little simulation of what it would be like to travel to a different planet type of thing, or how you could see the orbits getting warped with the different positions that you were in. Stuff like that, I think, was just easier to visualize, and you could feel like you were a part of it rather than learning about it.

For Laura, feeling as if she was “a part of it” (viewing the planets from space) allowed her to visualize the concepts of planets and their orbits more easily than learning about them in a classroom setting. Jennifer also discussed the concept of feeling as if she were in the environment being represented, but she focused her comments on observing the night sky. When asked to describe what the visualizations were like for her, Jennifer explained, “It felt like I was in the country by my house, looking at the stars.” Later in the interview, Jennifer described feelings of surprise at how realistic the stars looked to her since she had “seen it in reality.”

Physical Space. Another theme that emerged from participant interviews involved the physical space within the planetarium. As a part of the lesson, students sat on the floor in a concentric pattern within the five-meter diameter dome. Four participants discussed how this factor influenced their experiences in the planetarium.

Jennifer discussed her initial concern about the size of the planetarium when entering the auditorium. She stated, “When we first went in there, I was like, this is kind of tiny. This is gonna be crowded, it's gonna be weird. But then when we went in it really wasn't.” For Jennifer, the initial size of the inflated dome was something that she thought would be too small for the entire class to fit in. However, upon entering her fears were alleviated. She went on to elaborate about that experience of walking inside the planetarium space by saying, “I could see if I was a kid, how excited I would be for that, and then it honestly turned out to be really cool.”

Tiffany described a similar contrast between her initial feelings about seeing the size of the planetarium and her feelings once she entered the planetarium. She explained:

> When I got there me and my class was like there's no way we're gonna fit in there, there's no way it can be in there. And then when we got in there we like oh wow, this is pretty cool. So I thought it was pretty cool how it was setup.

While Tiffany did discuss thinking positively about walking into the planetarium space, she later expressed specific concerns about sitting on the floor due to her height. She stated, “I'm like

5’10” so I was really like scrunched up.” For Tiffany, sitting on the floor for the duration of the 45-minute planetarium lesson was an unpleasant experience due to her height, and she would later add that “it just kind of sucks being scrunched up for a while.”

Kayla and Laura also discussed the seating arrangements in the planetarium in relation to fitting a class of 20 adult students into the dome. During Kayla’s interview, she stated:

> I think that our class size was probably like the most amount that you should probably try to put in there. I think if it was bigger it would have felt a little claustrophobic having like, two rows of people in something like that. So I think our class size was good and even like smaller, which I guess if you were doing it with a bigger class you could do it in like two groups or something like that. But I thought that that was something that if there were more people it could've kind of taken away from the experience cause I would've been thinking about how I'm so like squeezed in.

For Kayla, the number of students in the planetarium was just the right amount. Students could sit in a single row with enough room to spread out, whereas with anymore students it may have meant having to sit much closer together or having a second row inside the planetarium. While she later explained that she did not feel uncomfortable in the planetarium, having more students sitting inside the dome would have detracted from her experience. Laura provided a similar response when saying, “It seems like it was a good size even with all of us squished in there. It wasn't uncomfortable or anything.” While Laura used the term “squished,” she elaborated on that idea by saying she did not feel uncomfortable in the space.

Research Sub-Question 3: What connections to outside events or experiences do preservice teachers make after participating in a live-interactive planetarium program?

As part of the reflection and interview questions, participants were asked to think about any ways the planetarium lesson related to any other events or experiences they have had. The participants responded in a variety of ways that are unique to each of them. To capture the diversity of responses, the results are presented in detail for each member of the study separately.

Casey. In both her reflection response and interview, Casey discussed several connections to outside events related to the planetarium program. She first described her personal interest in space, and later told a personal story about a connection with the night sky from her past. Casey also compared the planetarium lesson to other times she visited a planetarium. Finally, she mentioned an event that happened after the planetarium program where she was able to identify a moon phase.

A key discussion point for Casey was her personal interest in space. In her reflection response, she wrote, “I for one, love space. Stars are my favorite thing ever (I even have a tattoo of one!).” Casey made a similar statement during her interview when she said, “I personally love space. Like a lot. I actually have a tattoo of a star. It's something super important to me.” When asked to elaborate on these comments about why space is important to her, Casey explained, “It's weird to say but I just think that the fact that we're so small and there's so much else out there that we have no idea what it is in other galaxies and such is just so interesting.” She later added, “Then you think about leaving earth as a whole and leaving our galaxy as a whole and it just blows my mind that there's just an infinite amount of stuff out there. I can't even wrap my head around it.” These statements indicate some of the ways Casey thinks about space, and what she finds interesting in the concept.

Casey also made a connection between identifying the North Star in the planetarium and a personal story from her past. As previously discussed in this chapter, during the planetarium lesson Casey and Jennifer were sharing a social interaction. When asked during her interview to describe the interaction, Casey told a story about how she learned how to identify the North Star from her grandparents. That segment of the interview (Table 1) is provided below to capture the full details of Casey’s account.

Table 1

Interview Transcript with Casey

Speaker	Statement
Interviewer	[shows video clip] Okay, in this we're talking about constellations. There you were pointing at something. I was curious what you were pointing at. Do you remember? [end video clip]
Casey	I think we were talking about the North Star actually. I think I was showing [Jennifer], who was sitting next to me, something that honestly I think I was talking about a story at my grandparent's house. I think I previously mentioned it to her in a different class. Something where I had used the North Star. I identified it as you need to use it to go north. I think I was like, "That is the North Star." I know that before you were able to click something on the remote that named them all. I think that I was trying to prove to her that I knew it was the North Star before you put all the names on the screen.
Interviewer	Oh, okay. So you knew that that was the North Star. Expand on that a little. What kind of things did you do with your grandparents that you knew that that was the North Star?
Casey	We were boating on their lake and they had this light on their boat. I don't know. It was when I was really little. Something where their GPS or whatever we had at the time ... I was fairly little so I don't think Google Maps was a thing yet, which is weird to say because I'm not that old. We were pretty lost. We only had the light on this boat to guide us. My grandpa was telling us about how you can use the North Star to navigate where to go. Their house was on the northernmost point on the lake, which is fairly easy to find then at that point. You literally just follow it up. I thought that was a cool moment as a child and it sparked my interest for stars in that aspect because I never knew that there was one specific star that never moved location and was always north that you can use to follow and guided us home. That was cool for me as a child.

In telling this story, Casey highlighted multiple connections between the planetarium lesson and outside events. First, she made the connection between learning how to identify the North Star as a child on a boat with her grandparents and identifying the North Star in the planetarium. Next, she identified this event in her life as one that may have influenced her interest in stars. Finally, she discussed having previously shared this story with a friend, and how she used the lesson in the planetarium to reinforce with her friend that connection between her story and the concept being taught during that portion of the planetarium program.

During Casey's interview she also discussed having previously visited planetariums, and she made comparisons between those visits and the portable planetarium used in this study. She first stated:

> I actually remember going to one of those [portable planetariums] probably when I was in middle school. It was kind of neat to be able to see one again and be able to have that experience again. It was nice to be able to have something outside of the classroom to be able to attend and learn a lesson in.

When asked to compare her previous time in a portable planetarium to the one used in this study, Casey explained, "It was blue just like the one that we were in. It fit the same amount of people. It looked to be the same technology that would display the information."

Casey also discussed visiting another planetarium in her home town, a large metropolitan area in the Midwestern United States. During her interview, she stated:

> I went to our planetarium actually for the first time this summer. Being able to ... relate astronomy concepts to real life situations where I was able to go to the planetarium and learn more factual things about each planet and stuff and then to be able to have this class now and have even more deeper understanding and to have even more visuals in the portable planetarium it's cool to connect all those dots.

Casey described being able to connect a recent planetarium visit to the portable planetarium program used in this study. She was able to relate astronomy concepts and facts learned from a prior visit to the concepts and visuals used in the portable planetarium.

Finally, Casey mentioned making a connection between the planetarium and an outside event that occurred on the night prior to her interview. As she explained:

> I remember literally last night I got in an Uber because my parents were in town and I was able to look up and be like, 'It's almost a full moon. I know tomorrow is going to be a full moon.' I was able to realize the phases of the moon because we had been learning that in class.

In this example Casey provided, she described connecting learning about the phases of the moon in the planetarium with making an observation and a prediction about what the phase of the moon would be on the following night.

Jennifer. The connections that Jennifer made to outside events and experiences after participating in the planetarium program were focused mostly around living in a rural part of the Midwestern United States. Jennifer also discussed having made a connection between content in the planetarium and a movie she had seen.

In both her reflection response and during her interview, Jennifer made multiple references to her home town. When reflecting on the planetarium lesson she wrote, “I live in [a rural town] and it reminded me of being in the country back home.” When asked to elaborate on her feelings about growing up in her home town, Jennifer explained:

> I guess, we're in [University Town], which is a big city, and I'm like not a big city. I'm [from rural Midwestern United States], and so I'm used to being able to look outside my house to see the stars even, which not that you can't see them here, but they're just not as clear as they are at home.

For Jennifer, growing up in a rural town where she was able to see stars clearly at night, and attending school in a city was something that impacted the connections she made with the planetarium lesson. When asked to describe her experience in the planetarium, she stated, “I guess it felt like I was in the country by my house, looking at the stars.” Later in the interview, when Jennifer was asked to elaborate on if that connection with her home town might have influenced her experience in the planetarium, she stated:

> I had more experience with looking at the stars, ‘cause I do that all the time. Like I'll drive and just look at the stars. So then when I saw it in the planetarium, I guess maybe I would have expected not, for it not to look as real. But when I think it was one scene where it was like, you looked at just the stars and constellations, and that was like super real to me. And so it is not what I expected. I would have expected it to not look as real, since I've seen it in reality.

Jennifer's previous experiences with growing up in a rural town influenced her perceptions of the planetarium. Because she had experience with observing the stars in the clear skies back home, she did not expect the stars in the planetarium to look as real as they did.

Jennifer also made a connection between the content being discussed in the planetarium and a scene from the movie *Moana*. During the segment of the planetarium focused on the constellations, Jennifer at one point held her outstretched hand in front of her face and made an L-shape with her finger and thumb. When asked to describe this motion during her interview, Jennifer explained, "I was holding my hands out in an L-shape, and like diagonally towards the constellation." She further elaborated that "it was in *Moana* where she does that… and so she's trying to sail at the stars." When asked to explain how the scene from the movie related to the planetarium lesson, Jennifer said, "It was like we were looking at the stars and, I mean not that we were sailing but, I don't know. And not cause, I couldn't do that, like she did. I thought it was cool." Jennifer pointed out an interesting connection between talking about the constellations in the planetarium and a character in a movie who used the stars to navigate the seas.

Kayla. Kayla also made connections between outside events and the planetarium lesson. However, she discussed these connections in her interview, not in her reflection response. The topics that Kayla focused on included a prior visit to a planetarium, prior classroom lessons, and using a telescope.

The first connection that Kayla discussed in her interview was visiting another planetarium. She explained that she had never seen a portable planetarium before, but had visited a planetarium in a museum on a previous occasion. Kayla also compared her prior visit to a planetarium to the one used in the study. She stated, "I guess the museum was a much larger scale obviously cause it was in a big museum but I feel like what I was able to take from it was pretty much the same amount of information." Kayla further added:

> I went to the museum one in like elementary school, so I don't remember it super well, but I just remember we were like laying back in these chairs and stuff and looking up at the ceiling, and someone was saying all of it. Which you were able to do still in the portable one, so I think it still gave like the same experience as the big museum one.

Kayla noted the differences between attending a planetarium program in a museum and attending a program in a portable planetarium, but she also described the experiences as being similar.

Other connections that Kayla made involved her prior classroom exposure to astronomy concepts. As discussed previously in this chapter, Kayla made a connection between a kinesthetic activity in the planetarium by using her thumb to model the concept of rotation and a similar activity she learned in a geology class. While the two kinesthetic activities differed slightly, Kayla identified a similarity between the two. An additional connection Kayla made involved her high school astronomy class. She first stated, "I took astronomy in high school, so I already could, like, I knew a lot about the sky and stuff like that." Later in the interview, she provided additional details about her high school astronomy class, and explained:

> Well in my class, I took senior year of high school in the astronomy class, just in that actual, like, time in school in the class period was just kinda just like lecture type stuff and wasn't as interesting, I guess. It's still interesting, but not as exciting maybe.

In this statement, Kayla described the lecture format of her high school class not being as interesting as the planetarium. Kayla stated that what she found interesting about the planetarium lesson in comparison to her high school class was "being able to see the actual image of what was going on."

The final connection that Kayla talked about during her interview was getting to look through a telescope. She explained that as part of her astronomy class, her class visited a university's telescope on certain nights of the year. She described looking through the telescope as “one of the most clear pictures I've had of the night sky, until the planetarium.” She added, “But, I think the planetarium was the most, even better, because you were able to manipulate it more. Where just looking out of the telescope, it was just what was right there and wherever you did see.” During the interview, Kayla was asked to elaborate on her comparison between her telescope viewing and the planetarium. She stated:

> And it was a longer experience. Like when we would go to the telescope, it would be, it was like a public thing, so anyone could go to it, but our class would go. And so you'd be like waiting in a line, then you'd get to look for like 30 seconds or something, and then they'd move on to the next person. So it was still cool to be able to see and to be able to use that high quality of a telescope. But something like this was a lot more interactive and you got a more clear sense, and got to like actually see what was going on and what could be happening, I guess.

For Kayla, while she appreciated the quality of viewing objects through a telescope, she also valued the interactivity of the planetarium.

Laura. In both her reflection response and interview, Laura discussed multiple connections between the planetarium lesson and outside areas of her life. First, she mentioned having visited a planetarium previously, and she compared that with the planetarium program from this study. Additionally, she talked about her interest in space at a young age, and prior aspirations of becoming an astronaut. Finally, she described a personal connection between the planetarium and her grandfather.

In her interview, Laura brought up a previous visit to a planetarium. When mentioning her prior visit, she stated:

> I think I've been in a planetarium, but it was just like stars, and it wasn't seeing anything. I think it was just on automatic mode or something. I think we went to like a science museum… on a field trip one time, and it was just stars and that was it.

She also compared that planetarium to the portable one by saying, “I feel like this [portable] one definitely had more options of what it could do. I didn't realize planetariums had so many different settings and everything that you could show.” As discussed previously in this chapter, Laura was impressed with the technology used in the portable planetarium in comparison to the one she visited at a science museum.

Laura also described an interest in outer space when she was younger. During her interview, she stated, “I read a lot of space books when I was little. Not stories, but like the actual picture books with little captions and everything, and I thought it was really interesting when I was younger.” She added that in relation to the planetarium lesson, “since I just haven't read the same books or ever talked about space probably since then, other than in classes, it’s kind of like a fun jog of my memory, and getting a re-understanding of what everything was.” As Laura said, attending class in a planetarium was a way for her to connect to some of the memories she had about reading books about outer space.

Laura also discussed in both her reflection response and interview her desire as a child to be an astronaut. As part of her reflection, she wrote, “When I was little, I dreamed of being an astronaut. After I found out how much math and science went into it, I backed out!” When connecting that dream of becoming an astronaut to the planetarium lesson, she continued to write, “The planetarium made my younger self very happy! Although I couldn’t experience 0 gravity, I got to see what it looked like to travel in space.” This connection is similar to how Laura explained the planetarium program reminded her of reading books about space as a child. During her interview Laura elaborated on this connection, saying:

> I wanted to be an astronaut when I was little, because my aunt told me that astronauts are able to sleep on the ceiling…. So I wanted to experience zero gravity. My family loved going to [an air and space museum], and every time we would go, [I would ask], “Don't they have a zero-gravity simulator thing there?”... Anyway, every museum we went to, I always thought there would be one, and so I always asked for it, and they're like that's not really feasible.… So I think going into the planetarium, even though it's not like zero gravity or anything, it was exciting, because you kinda did like the moving through space thing.

As Laura explained, part of her idea of becoming an astronaut involved wanting to experience zero gravity, something she even asked about when visiting another museum as a child. While she recognized that the planetarium could not replicate the feeling of zero gravity, she felt as if the planetarium could recreate the feeling of moving through space.

The final connection that Laura made in both her reflection response and interview was about her grandfather. In her reflection, she wrote:

> My grandfather, who worked a lot with NASA, always loved teaching me about space. Although he was an ENT, he knew a lot about it. He is now 83 and is getting Alzheimer's. After seeing him over Thanksgiving break, the planetarium was a such a special way to come back to school. I wish I could call him and tell him all about it!

She further elaborated on this point in her interview, when she stated:

> My grandpa was a surgeon, and he worked a lot with NASA. Apparently, I thought he did some certain thing, but I was wrong. Obviously, it got lost in translation somewhere when I was younger, but I didn't realize how much he knew, because I was little, and I didn't understand how important he was with some of the discoveries, and then his own surgeries and everything. So experiencing some of this stuff again that he would like to talk to me about, and we would share, was kind of fun.

For Laura, her relationship with her grandfather helped her look forward to attending class in the planetarium. Additionally, after the planetarium program she felt an additional connection with her grandfather, and expressed a desire to discuss the planetarium lesson with him.

Tiffany. Tiffany also discussed the different connections she made between the planetarium program and outside events. Her comments were made only during her interview, and not in her reflection response. The connections she discussed included a preservice teacher workshop she took part in, and viewing a solar eclipse.

Several times throughout the interview, Tiffany discussed participating in a workshop for preservice teachers at a local science museum, and how that experience influenced her thinking about space science. She explained that during the workshop, "We kind of just went over, we chose the age group and we just went over the [state educational standards] in that age group of what they should learn and what they need to learn." She added, "They had us take a pretest, to see… what you need to focus on. A lot of us needed to focus on space science and I think a lot of us think oh that's not important." She further noted that her initial thoughts about space science were largely negative, and said, "I really actually like had a negative attitude about it at first, I really did. I was like I don't care, like I'll just teach them out the book." Next, she described how her thoughts changed after the planetarium:

> And then after I went to the planetarium I was like okay, now I actually want to teach them space science. Like this is really cool and then you can teach them something interactive. 'Cause when I learned about space science, it was boring. We just sat in the classroom and she just lectured. There was no, "Oh go outside and look at the moon you know, go outside and look at the sun. Can you see the sun?" It was none of that, it was just lecture, lecture, lecture. But I think the planetarium, is it got me engaged.

Prior to attending the planetarium program Tiffany described her thoughts about space science as being boring since her prior exposure to it had largely been lecture based; however, after the lesson in the planetarium she stated that she thought the content was interactive and engaging, and is something that she would want to teach.

Towards the end of the interview, Tiffany also mentioned her viewing the solar eclipse as another connection between the planetarium program and an outside event. When she discussed seeing the solar eclipse in August (three months prior to the planetarium lesson), Tiffany explained, "That was really my first time like hearing about it and really like understanding." At the time, she recalled thinking, "I'm like okay, so that was something that was like a big deal to scientists." Next, she described her thinking about the eclipse after hearing about it in the planetarium. She stated, "But after I like got the background behind it, I was like okay that's pretty cool. Like this is why this does this." In her statements, Tiffany described a change in her thoughts about the eclipse. When she observed the actual eclipse in August, she thought it was something that was of interest only to scientists; however, after getting additional information about the eclipse and viewing the simulated version in the planetarium she described finding it more it more interesting, and said she understood why it was happening better.

Research Sub-Question 4: In what ways are the experiences of preservice teachers in the planetarium educative, noneducative, or miseducative?

Participant responses to the reflection prompt and interview questions were analyzed to identify the ways in which their experiences were educative, miseducative, and/or noneducative, using the definitions for each term from Chapter 1. Themes that emerged from the analysis included *astronomy content*, *interactive activities*, *personal observations*, *sharing information*, *environmental responsibility,* and *future teaching practices*. Analysis of the data showed that each theme was a way that the planetarium was educative to one or more participants. However, some of the participants had miseducative experiences related to the theme of astronomy content. No examples of noneducative experiences were identified with the participants in this case study. Each theme is discussed in further detail in the subsequent sections.

Astronomy content. The most frequently discussed way the planetarium program impacted the experiences of participants involved shaping their understanding of astronomy content. Each participant discussed learning specific concepts to varying degrees. These concepts were related to the solar system and planets, constellations, the North Star, the motion and phases of the moon, solar eclipses, and the rotation of the earth. The facts and ideas participants discussed about these concepts were largely consistent with the planetarium program, meaning they were indicative of educative experiences; however, statements made by two participants regarding the rotation of the earth and the motion of the moon suggested there were portions of the planetarium program that may have been miseducative.

Educative experiences. The first example of an educative experience was discussed by Casey in her reflection. In her response she wrote,

> I learned many things which I never knew, and it was presented to us in a way which I never have been exposed to.… I never knew just how much stuff was beyond earth. The fact also that in our solar system that all the content together makes up 1% of the sun is insane.

In this statement Casey explained information being presented to her in a new way and learning a new concept related to the relative mass of objects in the solar system relative to the mass of the sun.

Another astronomy concept multiple participants discussed learning about because of the planetarium program was constellations. During her reflection Tiffany wrote, “It was cool to see the different types of constellations such as Ursa Minor and learn the origin of how they got their names and how to identify them.” In this statement Tiffany described learning about the origins and naming of constellations, and how to locate them. Casey also said she learned something similar. In her interview she stated:

> I didn't really realize that people… would use them as guides and stories. Like how they are animals or how they are archers or whatever shape that they formed. I just guess I didn't realize that there were so many stories and things behind them and how within them you can explain where planets are. You talked about I think it was Uranus or something that was in Pisces or something and how you can use them to… make direction out of where things are in the sky.

As Casey explained, she learned about some of the imagery and stories of the constellations, and that constellations could be used as a guide to identify the location of objects in the sky, such as planets. She also recalled a specific example from the planetarium lesson. Kayla was the final participant to discuss learning about constellations during the planetarium program. In her reflection she wrote, “Putting the constellations on top of the stars gave me a much better image of all of them because I am not able to find the constellations on my own when looking at the sky." Multiple times throughout Kayla's interview she repeated the idea that she was not able to locate constellations on her own. When asked to elaborate she explained:

> I feel like the most I learned from was the constellations, cause that's something that I've always been interested in, but for some reason I could never seem to really grasp it. So being able to see the full imagery in three different ways, like with the, just with the stars and then the connect the stars, and then the pictures ... it kind of made me be able to like, picture everything a lot ... better.

Kayla described the multiple visuals representations of constellations as being useful in helping her locate constellations, where she hadn't been able to before. For Tiffany, Casey, and Kayla, the ways the planetarium helped them learn about constellations are examples of educative experiences.

Another astronomy concept discussed by one participant was the North Star as a directional guide. During Laura's interview she discussed what she had learned in about the North Star, and stated:

> You were talking about how it changes positions… based on different parts of the earth you were in, right?…, and I always kinda wonder if I'm ever stranded somewhere, lost in the woods, how people always use the North star. So I feel like I would need it. Trying to understand that to at least know my direction without using a map or any kind of thing.

In her statement, Laura described knowing that the position of the North Star can change based on one's location, and that this concept can be used in helping with navigation. This idea is consistent with the content discussed in the planetarium program, and therefore indicative of an educative experience.

Another key astronomy concept two participants said they learned involved the motion of the moon and its phases. Casey had stated in her interview, "I was able to realize the phases of the moon because we had been learning that in class." She provided additional detail about using this information to correctly identify the phase of the moon on a particular night, which will be discussed in further detail in a later section. Tiffany also discussed learning about the phases of the moon in her interview. She stated:

> I learned… I didn't know there was a waning gibbous and waning crescent. I generally do not remember my teachers teaching me that in elementary school. I knew just full moon and new moon, the waxing crescent. I don't remember about the waning gibbous. And then I didn't know ... I also remember learning about third quarter.

In this statement Tiffany recalled previously only knowing about a few phases of the moon from previous classroom lessons, and described learning about new phases that she hadn't heard before.

Tiffany also discussed learning about how solar eclipses work as a result of the planetarium program. As discussed previously in this chapter, when she observed an actual solar eclipse occurring, she recalled thinking that it was "something that was like a big deal to scientists." However, after the planetarium program, she stated that she thought, "after I like got the background behind it, I was like okay that's pretty cool. Like this is why this does this." Tiffany's change in thinking about eclipses and having an understanding about how they work after the planetarium lesson is an example of an educative experience.

Miseducative experiences. While each participant made statements that were representative of educative experiences, Tiffany and Laura also expressed some ideas that were inconsistent with the concepts discussed in the planetarium. These concepts related to the rotation of the earth, and the motion of the moon.

During Tiffany's interview, she discussed relearning the concept of earth's rotation. She stated, "So I definitely got refreshed on like the basis of it takes 24 hours for the earth to go around the sun." In her statement, Tiffany appeared to confound the concepts of rotation and revolution since she references the length of earth's rotational period (24 hours) with the concept of the earth revolving around the sun. Since this statement is inconsistent with astronomical knowledge, it may be indicative of a miseducative experience; however, during the interview the researcher did not ask Tiffany to clarify her statement to determine if the mix up was a result of the planetarium lesson. It is also possible that Tiffany misspoke during her interview, or may have expressed a prior misconception.

Laura also made a statement indicative of a miseducative experience during a portion of the planetarium program. When discussing the visualizations of the motion of the moon, Laura stated:

> I don't think I really realized that [the moon] moved in one specific direction, and then would pop back over to where it was originally. I think I just hadn't realized that or thought about that in a while.

It appears from Laura's statement that she believed as part of the moon's motion it would "pop back" to its original position. During the planetarium lesson, the instructor used the software to illustrate that the moon would appear in different parts of the sky each night. This visualization makes it appear as if the moon instantly appears in a new spot on subsequent nights. For comparison of how the moon moved from its original location, the instructor reset the visuals to the starting date. Laura did not elaborate on the specific cause of her thinking, but it is possible the visualizations used in the planetarium led to her statements, which would be indicative of a miseducative experience.

Interactive activities. Another experience for participants in the planetarium involved interactive activities. Casey, Jennifer, Kayla, and Laura each discussed in their interviews some of the ways in which those activities were educative. The different interactive activities discussed by each participant were all kinesthetic, and included Casey modeling the rotation of the earth, modeling rotation with a thumb, and making the shape of the Milky Way galaxy.

Casey and Jennifer described how being a model to represent the rotation of the earth was educative. In her interview, Casey stated, “I was pretending to be the earth. I was rotating in front of the projector, which was the sun… I was rotating as if I was the earth to see how the sun casts light on the earth.” About this experience, she added:

> I think that when I would look around the room that students were responding well to having a different visual of how light is projected and how the earth revolves and rotates and stuff. I think it was a good example.

Casey mentioned that having a visual representation of light hitting the earth as it rotates was something she observed students responding well to. Jennifer also talked about how this model was helpful to her. In her interview, she stated:

> I think [Casey] was earth. It was when the sun was shining on her. Then it was like this time of day, that time of day, which was cool cause we had looked at it in class or in the planetarium, so then you could see it in real life…. since it was so dark in there, you could really see it, which for me helped. Like, I was able to understand it better.

For Jennifer, having the visual representation of someone modeling the light hitting the earth in the dark environment of the planetarium helped her understand the concept being taught.

Another example from the data was how Kayla and Tiffany described participating in the thumb activity to model earth’s rotation. As discussed earlier in the chapter, both students were unable to recall the specific concept the model was teaching; however, the act of participating in the activity led to additional thinking and making connections. Kayla explained:

> I'm in a geology class right now too and we actually… This is one of the things that we do for our test, like one of the things that we can remember. As like, this is how the planets rotate or something if we do this [holding thumb out, moving finger from other hand around thumb], and so, I guess those two kind of can tie together in a way.

While Kayla may not have recalled the exact details of the content, the activity led to her making a connection with another related concept, which can be classified as an educative experience. In a similar manner, Tiffany couldn’t fully articulate the concept being taught with the activity; however, she stated, “When you did the put your thumb out example, I felt that was really good and that was something like okay I can use that with my students in the future if they're confused." This statement indicated that participating in the activity prompted Tiffany's thinking about teaching students, which is indicative of an educative experience, and is discussed in more detail in a later section.

Finally, Laura discussed how participating in the kinesthetic activity to model the shape of the Milky Way galaxy was an educative experience. During her interview she stated how the activity allowed her to

> visualize how from our perspective if we ever see in the sky like the Milky Way, it looks like a straight line, 'cause we're only seeing the inside of it, 'cause we're on the inside of it. So we're only seeing the outer edge of one side rather than the whole thing.

She further elaborated that the activity

> helped me make sense of it, 'cause I guess I forgot that we were in the Milky Way, and so every time, you know, you can see it in the sky, which I don't know if I ever have. At least in images like why it's a straight line. I guess I never thought we're inside of it so we're only seeing one side of the circle.

Laura said that because of the activity she was able to visualize the reason the Milky Way galaxy appears as a line across the sky when it is spiral in shape. She also stated that this was something she had not previously thought about. In that way, the experience of participating in the activity was educative for her.

Personal observations. Statements made by two participants about making personal observations of the night sky after the planetarium program is another example of how the experience was educative. Casey and Tiffany both described making observations of the sky, or future plans to do so, after participating in the planetarium program. These statements were consistent with an educative experience, as information from the planetarium led to later thoughts and actions by the participants.

In her interview, Casey described having made observations in the sky after the planetarium lesson, and planning to make future observations. She first stated:

> Even I remember literally last night I got in an Uber because my parents were in town and I was able to look up and be like, 'It's almost a full moon. I know tomorrow is going to be a full moon.' I was able to realize the phases of the moon because we had been learning that in class.

Casey described viewing and correctly identifying the phase of the moon for that night, which she attributed to learning about during the class lesson in the planetarium. Additionally, Casey also explained how she planned to make future observations of the stars during an upcoming trip:

> I travel quite a bit. In the past I've never really taken a moment to realize how beautiful and how clear the skies are in different locations. I'm taking a trip to Arizona this December because I want to see the Grand Canyon. I'm going to drive up to Sedona and see the stars there because I guess it's some of the best star gazing. I'm just really excited to be able to see that in different light than a normal person would I guess just being like, 'Oh, a star.'

In describing her future plans, Casey expressed excitement about getting to see the stars in a new environment and from a different perspective. Both examples from Casey illustrated new thoughts and actions as a result of the planetarium program, which are representative of an educative experience.

Tiffany also discussed attempting to make observations of the night sky. During her interview, she stated:

> I've been trying to like see recently, trying to find a constellation and find a planet in the sky after you told us we could see them. I thought that was pretty cool. I actually have been like trying, I know I need to go further out like from more towards downtown to see them because isn't it more?... But I do go outside every once in a while and try to see it. Our skies, it was actually way clearer last week, they didn't have a lot of light pollution.

In her remarks, she described attempting to identify constellations and planets after discussing how to view them in the planetarium. Her statement also indicated that she understood that the further away from the city she got and the clearer the sky, the more she would be able to see, which was a concept briefly discussed in the planetarium. Tiffany's actions of attempting to observe the night sky based on information learned from the planetarium illustrate how the program was an educative experience for her.

Sharing information. Another participant, Tiffany, revealed her educative experience in the planetarium by discussing how she shared what she learned with her friends. During her interview, Tiffany stated that having attended the planetarium program "got me to share some of the stuff I learned with my friends." She added, "I shared with them that the constellations were like historically named by the Greeks and they all represent a certain picture. Like this represents an animal, this represents a Greek goddess. I thought that was pretty cool." In her comments, Tiffany described learning specific facts about how the constellations were named and the pictures that they form, and then sharing that information with her friends. In addition, Tiffany also stated that she told her friends about when to observe objects in the sky. She explained, "Then I told them like hey, you know you could see Venus if you wake up at 4:00 or you can see this planet." In both examples, Tiffany described taking information discussed during the planetarium lesson and sharing it with others.

Environmental responsibility. Another way in which the planetarium program was an educative experience for one participant, Casey, was by fostering thoughts about environmental responsibility even though that concept was not specifically addressed in the lesson. In both her reflection response and during her interview, Casey discussed coming out of the program with a respect for the delicate nature of life and an understanding of the need for environmental responsibility. In response to learning that the mass of all the objects in the solar system is less than 1% of the mass of the sun, Casey wrote in her reflection, "It makes me realize just how precious our planet is and how delicate its placement in the solar system is to sustain life." Casey also reinforced this idea in her interview. When asked how the planetarium program may have influenced her thinking, she stated,

> As for myself, I think I take a lot of things for granted as far as earth. It's kind of stupid but recycling. We need to, me myself, I need to take into consideration how precious this planet is. Like how cool is it that we have life here? What the heck? That's so cool."

While the concept of environmental responsibility and recycling were not specifically discussed in the planetarium program, Casey's comments represent educative experience because they are consistent with concepts discussed in the planetarium, specifically the mass of objects in the solar system and the requirements to support life. Casey extrapolated those concepts taught in the planetarium to arrive at a unique understanding of the need for environmental responsibility.

Future teaching practices. Finally, the planetarium program served as an educative experience in the ways it influenced participant thinking about future teaching practices. In their reflections and during their interviews, Jennifer, Kayla, and Tiffany discussed their thoughts about the use of planetariums in their future classrooms. Their responses included comments on using the planetarium to teach astronomy, the feelings students might have about visiting a planetarium, and specific teaching methods. While teaching practices were not a direct topic addressed within the planetarium lesson or the course in which the lesson took place, the lessons in the course were designed to model inquiry and constructivist teaching styles; therefore, ideas expressed related to and consistent with that aim would be representative of educative experiences.

Jennifer discussed her thoughts about using a planetarium with her students, and how they might react to such an environment. In her reflection response, she wrote**,** "I will definitely try to take my class to a planetarium – it makes science exciting!" Jennifer also focused on this idea of excitement during her interview. She explained, "I could see if I was a kid, how excited I would be for that, and then it honestly turned out to be really cool." When asked to elaborate on what she thought would be exciting for students about the planetarium, Jennifer stated:

> Well cause I think it's like cool to have a class not in your classroom. But then, how you can turn it into a learning experience, especially if it's a portable one, like you wouldn't even necessarily have to leave your school. And so I think they'd be really excited about it, and you could even not tell them. But you know then they see it and be really excited.

In this description, Jennifer expressed the idea that having a class outside of the standard classroom could be something that students would be excited about. She also discussed turning this out-of-classroom setting into a "learning experience" for her students. She later discussed how a planetarium would help teach science concepts:

> I think I would love to be able to do something like that in my classroom one day, cause sometimes science can be, especially astronomy, can be confusing. And cause it's all the way in the space and you can't really see it, and so I think that would be a really cool thing to have my class do and have that experience.

Jennifer expressed that using a planetarium with her class is something she could see herself doing because it could be a useful tool in teaching astronomy concepts to students.

Kayla also discussed how she would consider using a planetarium for students in the future. As part of her reflection response she wrote, "If this is something that is going to be available for schools in the future, and I could figure out how to use it, I think it would be such a beneficial lesson in a classroom." During her interview, she elaborated on this idea by saying:

> Well, I mean considering that I wanna be a teacher, I wrote about this in my reflection in class, but I feel like the planetarium is a technology that might be kind of difficult to get into every school. But if it was possible, I think that it's something that could be altered to any grade level. So, like, no matter what I was teaching, like if there was the younger kids, I could just focus on one thing. But up with the older kids, we could do something like we did, where like, you went through a lot of different topics and got us through a lot of different things. So, if that's something that's able to be in my teacher classroom I would love to use it because, I think that, especially for like during a unit on astronomy or planets or anything like that, it can give, like a much clearer picture. Cause I'm a very visual learner and so, I know for me and other kids who are like me, that was probably very beneficial.

Kayla first discussed having some concerns over the feasibility of having access to the technology and knowledge of how to use it, but explained that if those challenges could be overcome that she would like to use it for teaching students. Her comments discussed the ability to use the planetarium to teach multiple age groups and concepts. Additionally, she saw benefit in the visual nature of the planetarium as a teaching tool.

Tiffany also made several comments about future teaching practices, the first of which included using the planetarium as a teaching tool in the future. She wrote in her reflection, “I think the planetarium could be a great field trip for students in science when you [sic] covering the objective of space, sun, and the moon.” Similarly, Tiffany also stated in her interview, “If I do teach space and science, which I think I will go and teach fourth grade, fifth grade, then I will definitely probably consider doing a planetarium 'cause I thought that was really cool way for them to learn.” According to Tiffany’s statement, she thought the planetarium could be a valuable place to bring students to teaching specific space science content.

Tiffany focused many of her statements on the planetarium’s benefits for deaf education students. Her first comments on this topic regarded the space of the planetarium: “When I saw it, I was like, oh, that's something I could do with my children. For sure, because since I'm deaf ed, I only have five kids, so it will be easy to put them in there.” Next, her comments involved the benefits of the visual nature in the planetarium for deaf education students. She stated:

> I think the planetarium is great, because it's very visual. Deaf children are very, very visual, so it would actually probably be easiest for them to learn about the sun and the moon and the planets in the planetarium versus me just getting up and lecturing. So, versus, you know when a gen ed child, they could see the phases just going, and they'll get it. It'll probably be better for me to show the deaf ... One thing that my professor said, the deaf children need to experience it to remember it. And so them actually ... I think when you have the Live-Time going and you like fast forward time. I think that would be so great to be like, "Oh my god, wow. Like at 8:00, this is this or I can still see the moon at 4:00" I just thought that was just really cool.

Tiffany described seeing the visuals in the planetarium as one way to help deaf education students understand specific concepts as opposed to a traditional classroom model of lecture.

Tiffany also discussed her changing feelings about teaching astronomy as a result of the planetarium. As discussed earlier in this chapter, she mentioned that she had a negative view about teaching astronomy; however, after attending the planetarium program she stated that her views changed. She explained:

> After I went to the planetarium I was like okay, now I actually want to teach them space science. Like this is really cool and then you can teach them something interactive. 'Cause when I learned about space science, it was boring. We just sat in the classroom and she just lectured. There was no, "Oh go outside and look at the moon you know, go outside and look at the sun. Can you see the sun?" It was none of that, it was just lecture, lecture, lecture. But I think the planetarium, is if it got me engaged. I think it definitely would get children engaged.

Tiffany explained in her comments that her changing attitude towards teaching astronomy content was in part due to how it engaged her compared to previous lecture-based classes.

Lastly, Tiffany identified specific teaching methods she might use after seeing them in the planetarium lesson. During her interview, she discussed the kinesthetic activity of holding her thumb out to visualize the motion of objects as the earth rotates. While she couldn't remember the exact details during the interview, she recalled that it involved the sun and moon, and she stated, "When you did the put your thumb out example, I felt that was really good and that was something like okay I can use that with my students in the future if they're confused." Later in the interview she also described her feelings about the interactive activities. Tiffany stated:

> I thought it was a great, I thought it was a great visual. A lot of the stuff, when I'm in this class I really try to think how can I apply this to my students in a different way. 'Cause you know I ... So when you ask us a question or when you give us an example or you show us a picture, I'm like okay I could do it this way or I could do it this way instead of this way. So that's what I'm really thinking most of the time when we're learning content.

> And I'm also trying to learn it for myself but when we get your examples I'm like oh okay that's a good idea, and I jot that down like oh I can do this or I can do this or I can do that.

In her response, Tiffany explained that during the planetarium lesson she was thinking about various ways she could adapt the visuals and questions in the planetarium for use with her own students. Tiffany's comments regarding her thoughts about using what she was learning in the planetarium are indicative of an educative experience.

Conclusion

This chapter provided a description of the planetarium lesson used in this study, the ways in which the students participated in the planetarium, and their responses to the event. In answering the research question "*What are the experiences of preservice teachers who participate in a live-interactive portable planetarium program that uses a simulated immersive visual environment?*," the data showed that each participant's experiences were unique to them. Students interacted with the planetarium program in a variety of ways, including through questioning, kinesthetic activity, observation, making predictions, choosing the focus of content, and social communications with peers. Participant descriptions of their experiences included comments regarding novelty, technology, visuals, and physical space. The connections participants made between the planetarium lesson and outside events and experiences were largely unique to each person, and included personal family connections, real world observations, remembering related scenes from a movie, prior visits to planetariums, and classroom exposure. Lastly, when evaluating the ways in which the experiences in the planetarium were educative, miseducative, or noneducative, the data showed that the majority of experiences were educative, and were related to astronomy content, interactive activities, personal observations, sharing information, environmental responsibility, and future teaching practices. There were a few examples of miseducative experiences related to astronomy content that emerged from the data, and there were no examples of noneducative experiences. The results and their implications, along with limitations of this study, and future research possibilities are discussed in the following chapter.

CHAPTER 5. DISCUSSION

This chapter provides a discussion of the results based on each of the research sub-questions, as well as their implications for the science education and planetarium communities. Key discussion points include the role of interaction in a portable planetarium, the novelty of the portable planetarium, how planetariums build on prior experiences of audiences, and the educative value of experiences in a planetarium. Additionally, this chapter addresses limitations of the study and areas for future research.

Implications of Results

Role of Interaction in a Portable Planetarium

The results showed that participants interacted with the planetarium program in a variety of ways. These interactions included questioning, kinesthetic activity, observation, making predictions, choosing the focus of content, and social communications with peers. The types of interactive activities used in the planetarium were largely consistent with methods of other planetarium educators studied by researchers (Hartweg, 2016; Small & Plummer, 2010). These interactive activities were primarily directed by the instructor whose role was to understand and create an appropriate environment that would foster educative experiences (Dewey, 1938). In so doing, the instructor served as a more knowledgeable other (Vygotsky, 1978), and utilized interactive activities to facilitate social collaboration with students so they could “participate in new tasks, to learn new skills, … [and] learn new ways of using language” (Gibbons, 2006, p. 26). While the instructor played a significant role in the lesson and interactive activities that occurred in the planetarium, it is important to remember that learning through experience is a personal matter for the student (Simpson et al., 2005).

Participant responses indicated that the interactive elements of the lesson were helpful for a number of reasons. Kayla explained that the types of questions used by the instructor in the planetarium helped engage her in the lesson. She also described the multiple types of questions asked by the instructor (i.e. observation, recall, and explanation) as not being overly intimidating to answer. The interactive nature of the program also allowed the instructor to scaffold questions in such a way that encouraged active involvement from the participants. When the level of questioning remained focused on observation or recall, student interaction was higher than when students were asked to provide explanations for what was observed in the planetarium. Those students who did answer the more complex questions served as cognitive models for their peers (Bandura, 1989; Smart & Marshall, 2012). A prior survey of planetarium educators showed that one of the big challenges viewed by many professionals in the field is engaging audiences in a way that encourages them to think more deeply about the questions posed in the planetarium (Croft, 2008). The findings of the present study add to the previous findings by showing how participants thought about the various levels of interactive questions used during a planetarium program.

Kinesthetic activities were also described as being helpful in a variety of ways by the participants. Casey, Jennifer, and Laura discussed how the kinesthetic activities provided a model to help them visualize different concepts, such as the rotation of the earth, and the apparent shape of the Milky Way galaxy. This finding is consistent with results from other researchers that showed live-interactive methods in a planetarium (Bell, 1993; Carsten-Conner et al., 2015; Chastenay, 2016; Neece et al., 2013; Small & Plummer, 2014), as well as the use of models (Atwood & Atwood, 1995), were helpful in conceptualizations of ESS content. For some participants, the kinesthetic activities did not always result in the understanding of the concept being taught, as in the case of Tiffany and Kayla; however, reflecting on those activities generated thoughts and connections between experiences with similar models and ideas regarding future teaching practices.

While participants talked about multiple methods of interaction, they did not discuss every type of interactive activity used in the planetarium program. There was no discussion either during participant reflections or interviews about using fists to measure the height of the North Star in the sky. Additionally, neither making predictions in the planetarium nor choosing which planet to explore in greater detail were discussed. While video data showed the participants interacting with the planetarium lesson in these ways, it is difficult to evaluate their impact due to lack of participant response.

The most surprising result regarding interactions in the planetarium involved the students' communications with each other that occurred during the program. The majority of interactive activities were initiated by the instructor as part of the planetarium lesson design; however, the interactions between Casey and Jennifer occurred independently. While Casey recognized that her friendship with Jennifer often led to her talking about unrelated subjects during class, she was surprised by the nature of her conversations within the planetarium. During their interactions, Casey and Jennifer both shared information that was related to the lesson, and also personally relevant to them. Casey demonstrated prior knowledge of identifying the North Star by sharing her experiences with Jennifer. In addition, Jennifer shared a connection about how a character in a movie used the stars to navigate the seas. In these ways, both participants were sharing their competencies and experiences as members of a social community (Kutz, 1997; Wegner, 2000).

The role of social communication between audience members in planetarium programing is worth further consideration for planetarium educators. The value of social communication has long been understood in the teaching and learning of science concepts (Jornet & Roth; 2015; Leach & Scott, 2003; Lemke, 2001; Thier, 2002). Schnall et al. (2012) also recognize the ability for planetariums to facilitate social collaborations among participants. However, providing opportunities for these interactions to occur appears to be limited among planetarium educators. In a study evaluating the goals and practices of 36 planetarium educators and professionals, Small and Plummer (2010) found that only a single participant discussed incorporating time for students to talk to each other during planetarium lessons. Even in the present study, student-to-student interaction was not actively facilitated by the instructor; Casey and Jennifer engaged in those communications on their own. From participant interview statements, student talk within the planetarium can provide opportunities for meaningful sharing and constructing of knowledge to occur.

Novelty of the Portable Planetarium as an Educational Tool

A major discussion point for the participants regarding the planetarium program was the novelty of the experience. When participants described their experiences in the planetarium words such as “unique,” “cool,” “fun,” “awesome,” “interesting,” and “impressive” were used. Casey, Kayla, and Laura all discussed being amazed at the technology being used, and the versatility of the equipment to provide detailed visualizations of a wide variety objects, including the night sky, planets, and constellations. In addition, Kayla was impressed by being able to also show media clips inside the planetarium. Jennifer also mentioned how having an out-of-classroom experience in the planetarium would be exciting for students. These results are consistent with prior studies that showed technology can play a significant role in creating enjoyable experiences for planetarium audience members (Yu, 2005; Yu et al., 2014). In addition, use of such technologies as an educational tool appears to be consistent with statements of the NRC (2011), which explains that new technologies can “contextualize learning in engaging virtual environments.” (NRC, 2011, p. 67).

While the technology of the planetarium created novel and exciting experiences for the participants, it is important to use that technology to create educational value. Lemke (2001) stated that “having an exciting experience with science is valid and valuable in itself, but education must always be more than one great experience after another” (p. 310). One of the ways the participants described how the technology of the planetarium created educative experiences is through detailed simulated visual environments, which is described in detail in the following section.

Quality of the Simulated Immersive Visual Environment in a Portable Planetarium

Participants in the study made significant mention about the visual presentation used in the program. One of the types of observations discussed involved the ability to manipulate time and see the motion of objects in the sky as a result. This visual simulation was used to illustrate the concept of earth’s rotation over the course of a day, as well as the causes of the phases of the moon. Casey and Kayla both mentioned that they thought being able to see the changes occurring in the sky over time was interesting. Tiffany referred to this ability as “Live-Time,” and discussed how she thought that ability was valuable as a teaching tool. These statements were consistent with results from other researchers that found planetarium software could “allow students to make accurate observations of phenomena that could otherwise be completed only in the real world or in some cases not at all” (Bell & Trundle, 2008, p. 348). The findings of this study expand on the prior research by showing that participants find educational value in the act of making these types of simulated observations.

Another discussion point for two participants was the three-dimensional appearance of images in the planetarium. Jennifer discussed that the three-dimensional aspect of the visuals made it feel as if she was moving through space, and Casey identified the benefit of viewing representations of images in a domed setting compared to seeing flat images in a classroom setting. Several researchers have compared the impacts of using three-dimensional images in the planetarium compared with two-dimensional images to teach ESS concepts (Plummer et al., 2014; Sumners et al., 2008; Yu et al., 2015; Zimmerman et al., 2014). While this study did not specifically examine the conceptual impacts of the planetarium visualizations, the results expand on prior research by identifying that participants saw value in the three-dimensional effects created in the simulated environment.

Another factor that may have impacted the immersiveness of the environment, apart from the visualizations, was the physical space of the planetarium. Several participants discussed the proximity of other students while seated in the portable dome. While Jennifer noted initial skepticism about the size of the planetarium, she mentioned it wasn’t a concern after entering. Kayla and Laura explained that the number of students in the planetarium, 20, was probably the limit before they would start to feel uncomfortable. Tiffany, however, felt that she was a bit uncomfortable in the planetarium due to her height. The limited space within the planetarium is something that the participants identified as having impacted their experience. These results build upon the results of other studies that showed physical space was influential in the ways planetarium educators taught (Hartweg, 2016), and that immersiveness in the planetarium can be influenced by other environmental factors in addition to the visual presentation (Croft, 2008).

One particularly interesting finding regarding immersiveness came from Jennifer's discussion of realism within the planetarium. Because Jennifer had grown up in a rural town where she described observing stars in the night sky on a regular basis, it is surprising that she made the comment "it felt like I was in the country by my house, looking at the stars," when describing her planetarium experience. Even Jennifer made the comment that she was surprised by how realistic the simulated visual environment looked to her. This feeling of being present in the environment being simulated, or illusion, is a key component of immersiveness discussed by other researchers (Schnall et al., 2012; Slater, 2009). It appears as if, for Jennifer, the visual environment created in the planetarium was sufficient to create the illusion of observing a realistic depiction of the night sky. While it may seem surprising that the visual environment appeared realistic to her despite her background, it may very well be that her prior experiences from home served as a basis that influenced her perceptions of the planetarium as part of a continuity of experiences (Dewey, 1938).

The findings regarding the theme of realism also indicate the potential of the planetarium to recreate a realistic experience with nature through detailed visual representations. This finding is consistent with researchers who contend that one of the benefits of SIVEs is their ability to realistically represent universal truths of natural phenomena (Yu, 2005; Bell & Trundle, 2008). However, Dewey (1958) contends that there is more to experiencing nature than what can be empirically observed by stating, "The traits possessed by the subject-matters of experience are as genuine as the characteristics of sun and electron" (p. 2). Tsing (2005) further posits that while there may be universal truths in nature, individuals respond to that universality in different ways. While participants in a planetarium program may feel as if they are having a realistic experience of nature, and the experiences participants have inside the planetarium may be educative, this researcher has questions on the ability of technology to authentically replicate specific natural events. These questions are based on a personal experience of this researcher, and are explored in more detail in the supplemental Chapter 6.

One of the benefits from the quality of a SIVE in a planetarium may be the impact such an environment has on memories. Prior research has shown that an immersive environment was able to help students remember astronomical concepts long after the planetarium lesson (Sumners et al., 2008). The findings of this study expand on that by showing that the SIVE can also help stimulate memories of prior experiences, such as identifying the North Star on a lake, viewing the night sky back home, looking at celestial objects through a telescope, and childhood aspirations of wanting to become an astronaut. Despite questions on the ability of the planetarium to authentically simulate an environment, the findings of this study showed that the strength of SIVEs may not solely lie in their ability to create realistic visualizations of natural phenomena that can help with long term retention of content; rather, another benefit may come from creating access points for individuals to make personal connections to the planetarium program based on their own memories and prior experiences.

Building on Prior Experiences

Participant reflections and interview statements highlighted that they each had connections to astronomy and ESS concepts taught in the planetarium in a variety of ways that were unique to each of them. Connections that participants made included growing up in a rural town observing the night sky, prior visits to planetariums, experiences from other classes, professional development trainings, relationships with family members, and seeing other movies. These prior experiences shaped participant thinking about the content covered in the planetarium. Kayla's prior experiences of looking through telescopes with her class gave her an appreciation of the visualizations of the planetarium. Tiffany discussed how her views on teaching astronomy changed after the planetarium in relation to how she felt about teaching during her professional development. Laura went into detail how her time in the planetarium rekindled fond memories from childhood, and fostered connections with her grandfather. In addition to influencing participants' thoughts, the prior experiences of Casey and Jennifer, in particular, shaped the activity that occurred during the planetarium program. During the program, Casey shared a personal story with Jennifer about how she knew how to identify the North Star. Additionally, Jennifer used hand motions to represent a scene from a movie, where a character used the stars to navigate the seas.

The connections participants made were largely based on memories of prior experiences, and were fostered by the visual presentation created through the SIVE in the planetarium. These findings have implications for the planetarium community. If, as Dewey (1958) described, "all knowing and effort to know starts from… a deposit of prior experience, personal, and communal" (p. 428), then it is important for educators to connect these prior experiences to planetarium programming. However, Plummer and Small (2013) found that "rather than capitalizing on learners' current interests and prior knowledge, planetarium professionals appear to lean more towards generating new interests in their audiences" (p. 28). The findings of this study are relevant to planetarium educators, because they showed that even at times when the instructor was not actively attempting to connect the lesson with prior experiences, participants still made those connections on their own.

It is neither possible nor realistic for an educator to assess the prior connections of all audience members in a planetarium program; however, the visual representations of natural phenomena may encourage audiences to draw upon their own memories of prior related experiences. Tsing (2005) claims that nature is a universal concept that can facilitate new insights at local and individual levels based on different backgrounds and understandings. In this respect, planetarium educators may be able to use SIVEs to visually display the universality of natural phenomena as a way to build upon and connect with the vast prior experiences and memories of audiences. It is the role of the educator to facilitate these connections, and guide students in such a way that their personal connections to the content do not become miseducative (Dewey, 1938). The statements provided by the participants in this study expand on prior research by showing a variety of different connections audience members may have with the planetarium and ESS concepts that can serve as a basis for educative experiences in the planetarium.

The Educative Value of Experiences in the Planetarium

Participant responses regarding their thoughts and actions after participating in a planetarium program showed that preservice teachers can have educative experiences. Dewey (1938) described that "an experience is always what it is because of a transaction taking place between an individual and what, at the time, constitutes his environment" (p. 43). The educative value of the planetarium experience was unique to each participant. Additionally, in one sense, participation in the planetarium program could itself be considered an experience; however, the participants in this study described multiple transactions that occurred within the planetarium that could be considered experiences as well. These transactions included the different concepts discussed, interactive activities used, visualizations produced, and other thoughts from the participants.

The results showed that planetariums can be used to create astronomy content-related educative experiences through novel and detailed visualizations, as well as interactive activities.

Participants discussed thinking about concepts such as the solar system and planets, constellations, the North Star, the motion and phases of the moon, solar eclipses, and the rotation of the earth in new ways after exposure to those concepts in the planetarium. The thoughts and ideas about astronomy and ESS concepts expressed by the preservice teachers in this study were consistent with the planetarium program, and are in line with the core ideas described in ESS1-Earth's Place in the Universe (NGSS Lead States, 2013). Participant responses, therefore, showed that a planetarium program can be an effective tool in creating educative experiences consistent with national science standards as part of a science content course for preservice teachers. The findings are also important in the context of an abundance of research that has shown preservice teachers hold many deep-seated misconceptions about astronomy concepts (Abell et al., 2001; Atwood & Atwood, 1995; Bell & Trundle, 2008; Parker & Heywood, 2008; Plummer et al., 2010; Trumper, 2003; 2006; Trundle et al., 2007). A portable planetarium program as part of preservice teacher education may be one way to begin to address some of these misconceptions.

While the planetarium may provide preservice teachers with content-related educative experiences, some participants also provided statements that were indicative of miseducative experiences. Tiffany described a misconception about rotation and revolution, and Laura described a misconception in regards to the motion of the moon. With Laura's comments in particular, her misconception appeared to be a result of the visualization used as part of the program. Similarly, Carsten-Conner et al. (2015) found that some students still held misconceptions about the day/night cycle after participating in a live-interactive portable planetarium program. The results of the present study showed that while the planetarium can be used to create educative experiences, some participants may have miseducative experiences as well. While it is not possible for planetarium educators to address all the possible misconceptions of audience members, it is important that they structure the program in a way that guides audiences towards having an educative experience.

As an educative tool in preservice teacher education, the planetarium also fostered additional thinking about future teaching practices. Jennifer and Kayla discussed how the planetarium could be used to create an engaging, visual environment for teaching astronomy concepts. Tiffany described how her thoughts had changed about teaching astronomy. Prior to the planetarium, she did not have a favorable view of the topic; however, after the program she saw that it could be a beneficial tool in teaching deaf education students. Prior research showed preservice teachers had an increase in self-efficacy after teaching in a planetarium during a methods course (Maher et al., 2013). The findings of the present study build upon prior research by showing that the planetarium can also foster preservice teacher thinking about teaching practices as part of a content course.

An unexpected educative experience from this study was how the planetarium program fostered thoughts about environmental responsibility. Casey described having thoughts about the delicate nature of the planet, and the importance of recycling after the lesson. The NRC (2012) placed an increased emphasis on ESS content in the NGSS standards due to the “rapidly increasing relevance of earth science to so many aspects of human society” (p. 172), and Casey’s statements support that stance because she was able to relate content taught in the planetarium to other societal issues.

Another way planetariums can be educative experiences is by encouraging future actions, such as observing the night sky, and sharing information with friends. Casey and Tiffany both described making observations of the night sky after the planetarium program, and using the information they had learned to identify objects. Casey described observing the moon, knowing its current phase, and predicting its next phase for the following night. She additionally described future plans to observe the night sky on a trip to the Grand Canyon. Tiffany described attempting to identify a constellation and a planet based on knowing where they should be from the planetarium. Tiffany also mentioned sharing information she had learned about the constellations with her friends. Research from Plummer and Small (2013) showed that one of the goals planetarium professionals involved connecting students to the night sky. The findings of this study build upon that research by showing that for some participants, their experiences in the planetarium led to new connections with the night sky. This finding is also consistent with Dewey's (19838) view on the continuum of experience, where "every experience is a moving force" (p.38). The NRC (2012) also asserts that a "rich science education has the potential to capture students' sense of wonder about the world and to spark their desire to continue learning about science throughout their lives" (p. 28). The descriptions provided by Casey and Tiffany are indicative of how a planetarium can foster that desire for continued learning.

Limitations

There were several limitations to this study, which included the nature of qualitative case study research, the limited sample size, participant selection, and the role of the researcher as instructor of record. One limitation that came from using a case study approach with a social constructivism framework was the highly subjective and context-specific nature from which meaning was constructed and interpreted by the participants and researcher. Another limitation with a social constructivist framework was researcher bias in interpreting the data. To reduce this bias, the researcher conducted a participant-check against the interpretations drawn from the study. Additionally, it is difficult to generalize findings from a case study because the approach was designed to look at a phenomenon within a specific context with boundaries determined by the researcher.

There were also limitations with the sources of evidence collected during this study. The case study looked at the experiences of five participants in a planetarium setting, out of a possible 20 students. The participants were purposefully selected by the researcher to provide a maximum variation of results. However, a different selection process would have yielded different results.

This study also had limitations introduced by the role of the researcher, who was also instructor of record for the class. As the instructor, this researcher had an active role in the lesson design and activities within the planetarium program. Additionally, the relationship between the researcher as course instructor and the participants in this study may have influenced their responses. Participants were given instructions to respond honestly, and informed that their participation in the study was voluntary and would not impact their grades; however, it is possible that because of the researcher-participant relationship they may have censored their responses or answered questions in a more favorable manner than they otherwise would have.

Areas for Future Research

There are several areas of future research that may expand upon the present study. First, when discussing the interactive activities used in the planetarium lesson, some participants focused on certain activities while making no mention of others. Future studies may wish to examine the effectiveness of various types of activities used in live-interactive planetarium programs. Next, this study focused on a single 45-minute lesson, and one participant mentioned she would have appreciated more time in the planetarium to explore more concepts. Understanding the impact of either longer planetarium programs or multiple visits on the experiences of participants would be another area worthy of additional exploration. Furthermore, several students provided details about how the planetarium program influenced their thoughts and actions. Developing a longitudinal study would be beneficial to understanding the long-term impacts of planetarium experiences. Next, as a case study, the results of the present research occurred in a bounded environment. Additional studies could expand upon the perimeters of the present research to include different participants and settings. It would be worthwhile to examine the experiences of students of varying ages and backgrounds. In addition, conducting future research in multiple settings, such as fixed-dome planetariums, as well as other formal and informal environments, could provide insightful results. This study also raised additional questions about the role of realism as part of the experience of a simulated immersive visual environment, which is worthy of further consideration and exploration in future research. Lastly, the focus of this study was on experiences in a planetarium that utilized live-interactive teaching methods. Many planetariums also utilize full-dome movies to present highly detailed simulated visuals to audience members. Understanding how the experiences of participants differ in a full-dome movie program compared to a live-interactive one is another area for further exploration.

Conclusion

As national reform documents place increased emphasis on ESS concepts, it is important to provide preservice teachers with the experiences and content-knowledge needed to adequately teach those concepts to students. The results of this study showed that a portable planetarium can be useful as a tool capable of fostering educative experiences for preservice teachers. Modern technology has allowed for the creation of simulated immersive visual environments that can aid in the teaching of ESS concepts in novel and engaging ways. Live-interactive teaching methods in the planetarium can also foster student engagement and understanding of content. However, these methods are not a panacea to addressing all content-related concerns and misconceptions. Students may have misconceptions that they hold on to after a planetarium program, and it is possible that the visualizations used in the planetarium may serve as a miseducative experience if not properly addressed. It is for those reasons that conducting qualitative research on the experiences of students in the planetarium is important.

The results from this study also show that using a Deweyan framework to understand the experiences of participants in a planetarium program can provide illuminating information on the educative value of the event. Each audience member comes to the planetarium with their own personal background and experiences that shape their perspectives during and after the program; and while there may be commonalities, the experiences each participant has will be unique to them. It may not be possible to fully build on the prior experiences of all audience members in a planetarium program, but the use of live-interactive teaching methods in a portable planetarium allows for the opportunity to include audience members in the program in a way that may foster educative experiences.

CHAPTER 6. SUPPLEMENTAL

During the course of the present study, a significant astronomical event occurred. On August 21, 2017 a total solar eclipse was visible across much of the continental US. This event had particular relevance to me[1] as a science education researcher conducting a study on the use of a planetarium to provide preservice teachers with educative experiences with ESS concepts. I undertook several other projects related to the eclipse, including creating planetarium visualizations to simulate observing a total eclipse as well as launching a weather balloon to capture high-altitude video footage of the moon's umbra. In addition, I observed a total solar eclipse for the first time. My experiences with this event transformed my thinking, and left me with new perspectives. Those thoughts coupled with participant responses created questions for me on the role of the planetarium to simulate astronomical environments. While these questions were outside the bounds of the case study, they were worthy of further discussion in a supplemental chapter. This chapter provides a description of those experiences, followed by an examination of my experiences through a Deweyan lens, and a discussion of the connections between my experiences and the present study.

Description of Eclipse Experience

Project Stratoclipse

My experience with viewing the total solar eclipse was the culmination of several events. One year prior to the eclipse, a friend and colleague, Blake, informed me that his family owned a ranch which happened to be in the path of totality, and that we could have access to it. With this information, Blake and I began researching the possibility of launching a weather balloon to

[1] In contrast to the previous chapters that used a third-person voice to place the focus on the voices of the participants of the study, first-person voice is used in this chapter to accurately represent my experiences and thoughts as a researcher.

capture high definition video footage of the eclipse from high-altitude. We had been inspired to do something like this after seeing video footage posted on the Internet of hobbyists using off-the-shelf equipment carried by a weather balloon to record video from high altitude; however, very few people had done something similar during an eclipse. This served as the basis for the formation of Project Stratoclipse.

The goals of Project Stratoclipse were to capture high-definition video footage from high-altitude of the moon's shadow (umbra) moving across the earth for use in a planetarium program, and to educate people about the solar eclipse that would occur on August 21, 2017. To begin, Blake and I started researching and obtaining the materials we would need for the project. We learned that our weather balloon would need to reach an altitude of over 30,000 meters, and that the video recorder and tracking device would need to be well insulated. This altitude would allow us to get video footage that was stable, and not shaking due to interference from the jet stream like several other examples we had seen. Additionally, we familiarized ourselves with the FAA regulations to make sure we remained in accordance with federal guidelines. Blake and I also spent significant amounts of time researching different ways others had used weather balloons to record video footage, since neither of us had attempted before task like this before. In addition, we co-authored an editorial for the local newspaper of the small rural town in the middle of the United States where we would conduct the project. The purpose of the article to inform the community about the eclipse and how the event might impact the town. During this time, I also worked with a science museum and its planetarium staff to develop a full-dome movie that simulated what it would look like to view an eclipse. Furthermore, Blake and I partnered with an aviation museum in the southwestern US to obtain funding and materials necessary for the project, and in return, develop program curriculum for their visitors. I enlisted the help of several other team members to help with the event, including a photographer, and a documentary crew. Lastly, as the eclipse day grew closer, I created an Internet channel [2]to upload videos and livestream our activities during the week leading up to the eclipse. This information was shared with family and friends, as well as teachers and museums to use with their students and visitors.

The events leading up to the day of the eclipse were full of multiple challenges. Our first test launch months prior to the actual event was unsuccessful because we used helium from a party store, and we subsequently learned that the quality of helium plays an important role in helping the weather balloon reach high-altitude. Our dress rehearsal launch, which was two days prior to the eclipse, demonstrated that our balloon could successfully reach the desired altitude. Additionally, we were able to successfully track and retrieve the payload (despite a near miss call where the materials landed 150 meters from a major river). However, during this test the video recording devices were so well insulated that they overheated and did not record any of the flight. This issue led us to having to redesign our payload carrier just one day before the eclipse.

Eclipse Day

August 21, 2017 is a day that I will not forget. On the morning of the eclipse, the sky appeared bright orange as the sun began to rise above the town's water tower, illuminating the county road and surrounding soybean fields. As I sat in my camping chair, eating a bowl of instant oatmeal, I reflected on the week prior that had led to this point. I remembered arriving in the small, beautiful town, not knowing what to expect; and developing a relationship with our host, Don, who graciously let us use his farmland as a base of operations. I felt a particular bond with Don, who treated me like part of his family from the moment we first met just five days

[2] Listed on Youtube.com as "Project Stratoclipse," with the URL: https://www.youtube.com/channel/UCMQ16pCfl6l96N1lzjkKycA

prior. My thoughts also drifted to thinking about my family. I wanted to bring my six-year-old son to see the eclipse, but decided not to over concerns about the camping environment and possibilities of storms. I also had feelings of nervousness. While the sun was shining and the sky appeared clear this morning, I had been checking the weather forecast continually, and knew there was a chance of storms that would come in without warning and block our view of the eclipse similar to the surprise storm that appeared early one morning two days prior that had nearly destroyed our tents and supplies.

I also felt prepared to launch our weather balloon later that day. I mentally ran through the final checklist of what I needed to accomplish. Those feelings of preparedness came with feelings of frustration as Blake and I had argued the night before on final payload design options. Our last test, while successfully launched and recovered, failed to properly record the flight. We had spent thirteen hours the day before going through engineering principles of testing and retesting to isolate the problem and design a solution. While helpful, this process led to tension between Blake and I, and as we entered the midnight hour, I made the final call about our design against his protestations. All these thoughts, and more, went through my head as the eclipse drew near.

As the morning continued, Blake and I prepared to launch our weather balloon as more and more people arrived to view the launch as well as the eclipse. We were joined by the documentary crew, friends of our host, and curious onlookers including a group of Mennonites. Unfortunately, along with more visitors came more and more clouds, until eventually the sky turned to a dull gray with no view of the sun. At that moment, I recall not feeling deterred by the weather, as I had a task to accomplish, and even if the clouds blocked the eclipse from our view, the weather balloon would still capture the event from high-altitude.

With crowds looking on, Blake and I prepared the weather balloon for launch. We completed the tasks on our checklist while livestreaming the event to audiences on the Internet. During preparations, our helium tank ran out of helium while it was filling the balloon. Thoughts of frustration entered my head, as Blake and I purchased more than twice the amount of helium we calculated we would need for the flight. The weather balloon was filled with just enough helium to lift our payload off the ground, but not enough to bring it to high altitude. However, I was determined to make this project that I spent the past year working towards be successful. Our payload needed to be 200g lighter than it was. Having run through many design scenarios the prior night, we were prepared to remove some of the equipment from the payload if needed. We quickly made the call to remove one of the cameras from our payload to shed the weight. The drawback to this decision was that we only had one camera capturing video footage instead of two; however, that decision was better than the alternative in which we would have been unable to launch any cameras.

At 11:00am on that day, two hours before eclipse totality, and underneath a clouded sky, we launched our weather balloon. The feeling of accomplishment was euphoric. This project had gone through many ups and downs over the past year, but once the balloon was released I knew that it had been worth it. After the balloon launched, all that was left to do was track it, wait for it to come down, and hope the clouds cleared so that I could see the eclipse from the ground.

After launch, despite being unable to view the eclipse under the cloudy sky, the dance between the sun, earth, and moon continued on as the moon slowly blocked more and more of the sun. I grew more and more hesitant. While I had reassurance that our balloon was making process from being able to track its GPS signal, I became increasingly worried that I would miss seeing my first total solar eclipse from the ground.

Twenty-five minutes before totality, the skies to the south of our location cleared. I recall telling all the spectators that if they wanted to see the eclipse happen, they needed to get in their cars and drive as far south as possible. Another friend (James) and I did the same. We drove as fast as we could down a county road that was lined with other spectators pulled off into the dirt with hopes of viewing the eclipse. As the sky began to change colors from a light blue to a dark purple, we arrived at a junction where many other cars were pulled over, and decided this would be the best place to stop.

James and I got out of the car with two minutes before totality. We could see the eclipse occurring through a small break in the clouds, and knew we would get to witness something spectacular. Through solar viewing glass, the sun appeared to be a thin sliver of light as the moon moved in front of it. The ambient temperature had become noticeably cooler, and the sky was an eerie deep purple with orange coloration surrounding the horizon in all directions, a similar color to what I had observed during sunrise that morning. As time slowly inched forward, the anticipation in the air from myself and fellow spectators was palpable.

Then, the moon completely covered the sun. In that moment, I removed my solar viewing glasses, and witnessed something that is beyond description. The sky was dark, and other stars in the sky became visible. But the main attraction in the sky was the sun, or lack thereof. Where the sun was, only moments ago, there was now a black circle surrounded by brilliant white light from the corona of the sun. In that moment, I wanted to take a picture of the event with the camera on my phone, but I made the conscious decision to enjoy the moment for myself. There were cheers and applause coming from others around me, but I was speechless. I was moved to tears. Others had told me about the brilliance of the event that was now before my eyes. As a science educator, I had shared this information with others. I thought I knew what to expect. But in that moment, I was wholly unprepared for what I was witnessing. Later that day, when reflecting on the experience, I wrote "Completely cloudy right until totality. That was something I will never forget. My planetarium show where I tried to simulate the experience of a total solar eclipse seems wholly inadequate to describe the experience" (Personal communication, August 21, 2017).

Then, three and a half minutes after totality began, which felt simultaneously like an eternity and an instant, it was over. The sky transitioned back to a normal daytime blue. The temperature warmed back up. James and I drove back to share our experiences with those who stayed behind. We found out that those who stayed behind were able to also have a view of totality, albeit through the haze of wispy clouds. In sharing my story and hearing others recount their experiences, I was in a sense of euphoria. I had a new appreciation of something that I had spent my career talking about with others, but had never experienced before.

Later in the day, Blake and I recovered the balloon we had launched that morning in an open field about 60 miles from its origin point. As we approached the site, we were hesitant, wondering whether or not the last-minute design changes we made worked, and if the camera had captured the desired footage. Blake wasted no time. He opened the payload where we found it, and immediately checked to see if we captured the footage we wanted. Looking at the tiny camera display, we could see that our project had been a success. The footage we captured was better than we had hoped. On the return drive home, we felt like champions. We had witnessed our first total solar eclipse, and successfully launched a weather balloon that recorded high definition footage of the moon's shadow moving across the surface of the earth.

Later that night, I wrote a reflection about my experience. My reflection entry is presented in its complete and unedited form below (Table 2).

Table 2

Reflection Entry Dated August 21, 2017

> "Today was an awesome day. Launched and recovered a weather balloon that captured the umbra. Despite some last minute hiccups and needing to call an audible, we launched at such a rate that our balloon hit it's burst altitude during totality while in the umbra. The chances of that happening are crazy!
>
> Not to mention worrying about not being able to see the eclipse because of completely cloudy skies. We made a last minute call at 12:45pm (25 minutes before totality) to get in the car and drive when it looked like the clouds were clearing to the south. We found a place to stop 3 minutes before totality, and got to see the entire thing.
>
> Part of me wants to share pictures from what other people in my party took (I didn't take a single one- I made a conscious choice and forced myself to just enjoy the moment without pulling out my phone) , but honestly any pictures I share wouldn't do it justice.
>
> During a TED Talk, David Baron said "You won't believe me when I tell you, but you owe it to yourself to see a total solar eclipse before you die." This is how I feel. As a science educator, I thought I knew about a total solar eclipse. I've taught about it, created a planetarium show about it, trained teachers how to view it with their students, and I've even seen partial solar eclipses. But, I was wholly unprepared for the event. Words and pictures can convey some of it, but you can't truly know how transformative an experience it is until you see one for yourself.
>
> So... you won't believe me when I tell you, but you owe it to yourself to see a total solar eclipse before you die."

After the eclipse

The days and weeks following my eclipse experience were a time of much reflection. I was grateful I had the opportunity for the experience, but full of questions about the implications of my new perspective. Viewing the eclipse was a transformative experience for me, and it highlighted the limitations of how to simulate the visual experience of viewing an eclipse in a planetarium. The planetarium show I had created months before, which had been recognized and awarded top honors by the American Astronomical Society, now seemed juvenile and inadequate in comparison. I was left with the question: *is it possible to fully recreate the experience of viewing an eclipse in the planetarium?*

Blake and I also continued to work with the video footage we captured to create a short movie of our weather balloon's flight. The goal of the film was to be educational, highlight information about eclipse dynamics, and culminate with views of the moon's shadow moving across earth's surface. While the video achieves its goals, it does not capture or adequately represent the eclipse experience. Scenes from this film are edited and used in the planetarium program for this study.

My experience viewing the eclipse also inspired me to get my first tattoo. This idea is something that had occurred to me after talking with others who had viewed multiple eclipses, and got tattoos to commemorate the experience. This topic was one on which I reflected in my journal. The account appears below (Table 3).

Table 3

Reflection Entry Dated September 3, 2017

After a lot of thought, yesterday I finally got my first tattoo. I'd thought about getting one in college, but there was nothing back then that I would have wanted permanently. Well, after seeing my first total eclipse, I knew what I should get. There really is nothing like seeing a total eclipse. It is indescribable, and for me as a science educator it was perspective changing. The tattoo is a reminder to myself that even though I can teach you what you need to know about science to pass a test, that's no substitute for the real world experience. Some things you just have to see for yourself. Also my plan is to add the dates of each new total eclipse I see.

The thoughts recorded in my reflection journal highlight the impact viewing an eclipse had on my perspectives as an educator. They also show my thinking about the role of simulating experiences, in that there may be some events that people need to experience in person.

Deweyan Perspectives on My Experience

Dewey's view on the continuum of experiences differentiates between experiences, and *an* experience. While experiences may involve a continuous flow of active and passive elements, they are often only loosely connected and limited in scope. In contrast, *an* experience occurs

> when the material experienced runs its course to fulfillment. Then and then only is it integrated within and demarcated in the general stream of experience from other experiences… Such an experience is a whole and carries with it is own individualizing quality and self-sufficiency (Dewey 2005/1934, p. 36-37).

Dewey further elaborated that *an* experience may include aesthetic components which involve "a degree of completeness of living in the experience of making and of perceiving" (p. 27). Additionally, an aesthetic experience is both intellectual and emotional. The experience leads to intellectual inquiry about what is being perceived, and "the experience itself has a satisfying emotional quality because it possesses internal integration and fulfillment reached through ordered and organized movement" (pp. 39-40). An aesthetic experience involves an active level of participation, and it is transformative, where the experiencer is left with a new or deeper understanding than before.

Under this framework of experience, I would consider my viewing the eclipse to be an aesthetic experience. The eclipse itself was a singular event that I perceived, but it also represented the culmination of over a year's worth of preparations and activities in which I was actively involved. The act of viewing the eclipse was also both intellectual and emotional for me. In that moment, I was thinking about the motions of the sun, earth, and moon along with their relative proportional sizes that make total solar eclipses possible; however, perhaps more importantly, that thinking about the "ordered and organized movement" of what I was observing was deeply moving on an emotional level. In observing the movements between celestial bodies, I felt a deeper connection to the Universe than I ever had before. Lastly, the experience left me with a more profound understanding about solar eclipses, and a new perspective about my role as a science educator. Before my experience, my understanding of eclipses was limited to the physical mechanisms that allowed for the event to occur, but after my experience, I now understand that there is an aesthetic quality that is not easily reproduced or simulated. This understanding has impacted my perspectives as an educator by demonstrating that while teachers can teach science concepts in the classroom, there is a qualitative aspect to those concepts that must be experienced to in real-life to gain a deeper understanding.

Connections to Present Study

There are connections between my eclipse experience and the planetarium program used in the present study. One of the segments in the planetarium program used media clips to simulate the visual appearance of a total eclipse from multiple perspectives. Additionally, scenes from captured high altitude footage as a part of Project Stratoclipse were displayed in the planetarium. During an interview with Kayla, she discussed being impressed with the technology that could show media clips in the planetarium, specifically mentioning the high-altitude footage. She stated, “I really liked how you played your video on the, like, the actual video that you took when you set your balloon up on the thing… it was really cool seeing it up on the screen.” This comment was the extent of Kayla’s discussion about the clip, which focused on the technical and visual aspects of being able to display video clips on the domed screen.

Only one other participant discussed the solar eclipse as part of the planetarium program. As discussed in prior chapters, Tiffany’s statements about connections she made to outside events focused on recalling seeing the eclipse on August 21, 2017 (which she would have seen as a partial eclipse from her location), and changes in her thoughts about how eclipses work after the planetarium program. I recorded my thoughts about the lack of discussion from participants about the solar eclipse in my reflection journal, presented as Table 4 below:

Table 4

Reflection Entry Dated December 7, 2017

On a personal level, I am disappointed that more students did not talk about the eclipse during their interviews. This was a meaningful event to me, and I would have liked for my students to have a better understanding from the planetarium. However, I am not surprised by this. Even after all my prior work in the planetarium, I did not understand how beautiful seeing a total solar eclipse is until I saw one for myself. Why should I expect anything else from my students?

These thoughts are representative of my questions on the role of the planetarium in simulating various events. While Tiffany's statements about having a new appreciation regarding the mechanics of solar eclipses indicated an educative experience, it does not appear that any of the participants had an aesthetic experience regarding the eclipse that was simulated in the planetarium.

A counterargument could be made about the ability of the planetarium to create realistic simulations based on participant responses regarding the theme of realism. As discussed previously, Casey, Kayla, and Laura talked about the quality of the images appearing realistic; however, the most intriguing result came from Jennifer's interview statement when she described feeling as if she were observing the night sky back home. In my reflection log, I wrote "Jennifer discussed being surprised about how real the stars looked in the planetarium. I am also surprised that she had this reaction, particularly due to her prior experiences" (Personal communication, December 5, 2017). I found her response surprising because after having observed stars in a dark sky like her, I can tell a distinct difference in quality of the appearance of stars in the actual night sky compared to a simulated image in a planetarium. Despite these thoughts, it appears that for some audience members the SIVE created in the planetarium can promote feelings of being present in the environment. This finding raises another potential question worthy of further exploration: *is experiencing a celestial event through simulation sufficient for recreating the phenomenon if the person feels as if the experience is genuine, or do some events need to be experienced in real-life to have a more complete understanding?* I suspect that the answer to this question will be unique to each person based on individual backgrounds and preferences, as Dewey (1958) posits that “the traits possessed by the subject-matters of experience are as genuine as the characteristics of sun and electron” (p. 2).

Implications

The use of technology to create an authentic simulation of an environment inside a planetarium is one of the benefits of SIVEs discussed by several researchers. Some researchers argue that planetariums have the ability to create a sense of immersion, which includes feelings of being present in the simulated environment (Schnall et al., 2012). These immersive environments have also been shown to have positive cognitive impacts, such as long-term content retention, and increased student engagement (Elvert, 2015; Law, 2006; Sumners et al., 2008; Wyatt, 2005; Yu, 2005). Slater (2009) claims that “in an ideal immersive system it is possible in principle to fully simulate what it is like to go into a non-immersive system” (p. 3550). Additionally, Yu (2005) posits that “a carefully constructed [visual environment] allows users to gain direct experience about a place or phenomenon that would otherwise be difficult or impossible to observe in real life” (p. 6). This point is an important one to consider, when understanding the value of SIVEs, as there are those who may never get the opportunity to have a genuine experience viewing an eclipse, or other celestial phenomena. The environment created in the planetarium may represent the only exposure to these events that some will ever have.

There are merits to the claims of immersion shown through prior research. Results from this study corroborated findings from Bell and Trundle (2008) that showed the planetarium can be used to help participants to quickly observe changes in moon phases that would otherwise require a long period of time. In addition, educators can also use planetariums to demonstrate how much easier it is to see stars in a dark sky that is free of light-pollution. This potential impact of the planetarium was discussed by Neil deGrasse Tyson (2004), who recounted his personal experience of growing up in New York and seeing the stars under a dark sky for the first time during a visit to his local planetarium as being a key life-event that set him on his path to become an astronomer and planetarium director. Additionally, results from this study indicated that there is value in how SIVEs can create access points for audiences to connect with the lesson. In these ways, the research has shown that the feeling of a realistic experience through SIVEs provides positive benefits that warrant its continued use; however, on a personal level, I am still left thinking that simulation cannot serve as a substitute for certain experiences.

Other science institutions, such as zoos and aquariums, do something similar to planetariums by simulating environments. These environments allow visitors to observe exotic animals they otherwise would not be able to see, often times in simulated natural habitats. Zoos put a considerable amount of time, money, and effort in recreating a simulated natural environment for visitors to “learn more about and enjoy nature” (Catlbog-Sinha, 2008, p. 156). These simulated environments may recreate elements of animals living in a natural habitat including sights, smells, and behaviors that one would expect to observe, and they can also influence the thinking and future actions of visitors. However, there is a distinct difference between the experiences of seeing animals in a zoo, and traveling to observe wild animals in their natural habitats. Ryan and Saward contend that zoos are not an “effective substitute for viewing wildlife in their natural settings” (Ryan & Saward, 2004, p. 260).

My experiences in planetarium research along with viewing a total solar eclipse in person have highlighted for me that while planetariums may be able to create highly detailed SIVEs that have educational value, they cannot fully replicate some real-world experiences. First, the visual simulations I used during my planetarium program, as well as others I have seen since, failed to adequately represent the appearance of total solar eclipse. For instance, distinct visual subtleties occur during an eclipse, such as the sun’s corona, which I have yet to see accurately represented in pictures or video. Furthermore, observing a total solar eclipse is more than just a visual experience. Distinct environmental changes occur during a solar eclipse, such as a sudden drop in temperature and noticeable changes in animal behavior that cannot be replicated in a planetarium.

While it may be beyond the capabilities of current planetarium technologies to fully recreate the essence of real world experiences, there is value in the use of SIVEs in the planetarium, and it is therefore important to consider the purposes for and implications of their use. SIVEs can provide educative experiences, as well as engage audiences and inspire them to seek out the genuine experience for themselves. Additionally, the visualizations in the planetarium created access points that allowed participants to draw upon prior experiences and memories in ways that made the experience feel real to them. Results from this study showed that participants had several educative experiences, and were engaged in the program largely because of the SIVE created within the planetarium. The findings that showed participants were encouraged to make observations of the moon and stars on their own after the planetarium program are consistent with one of the major goals of planetarium educators, which is to increase personal interest in astronomy beyond the planetarium setting (Plummer & Small, 2013). As long as educators are aware of the benefits and limitations of SIVEs, sufficient evidence exists to support their continued use in planetariums.

Conclusion

My personal experience viewing a total eclipse was an example of an aesthetic experience that provided me with a deeper understanding about eclipses as well as new perspectives about the role of planetariums. It also made me consider two questions. The first was, *is it possible to fully recreate the experience of viewing an eclipse in the planetarium?* I do not have a definitive answer to this question; however, from my experiences I think there are certain qualities about celestial events such as solar eclipses that cannot be easily simulated. Technology is ever evolving, and it may someday be possible to recreate conditions that adequately simulate the experience. The second question raised based on findings from this study was, *is experiencing a celestial event through simulation sufficient for recreating the phenomenon if the person feels as if the experience is genuine, or do some events need to be experienced in real-life to have a more complete understanding?* This question may not have a singular answer, as each individual comes from a unique background with a plethora of prior experiences that shape their views. Those who have seen a total solar eclipse in person may feel as if a simulated version of the event cannot truly capture the experience, whereas others with no prior background of the event may find the simulation to be a sufficient representation of the event. Additionally, due to the rarity of seeing a total solar eclipse, the simulated event may be the closest thing to a real-world experience that some people will ever have. However, results from this study have shown that planetarium technology can create feelings of realism as well as access points for personal connections. In addition, planetarium technology can engage and inspire audiences through the visual presentation. The experiences and feelings of these participants, as well as other planetarium audience members, should not be discounted. While creating high-quality, realistic, immersive visualizations has many benefits, it is important not to develop such environments solely for the sake of realism. Rather, SIVEs should be used to present the universality of nature in a way that provides access points for individuals to connect with the planetarium in a variety of ways. There may not be definitive answers to the questions posed in this chapter, but they are worthy of consideration for researchers and planetarium educators as well as those seeking to pursue life-long learning in an ever-expanding Universe of endless possibilities.

Appendix A

Texas Christian University
Fort Worth, Texas

CONSENT TO PARTICIPATE IN RESEARCH

2014 IRB# – 1408-87-1408CR *2015 IRB# - 1408-87-1510AM*
2016 IRB# - 1408-087-1608CR *2016 IRB# - 1408-87-1608AM2*
2016 IRB# - 1408-87-1608AM3 *2017 IRB# 1408-087-1608AM4*

Title of Research: Education Majors Research Project - 2014-2019

Study Investigators: Dr. Weinburgh

Other professors: Dr. Bauml, Dr. Faggella-Luby, Dr. Quebec-Fuentes, Dr. Griffith, Dr. Alexander, Dr. Steve Przymus, Dr. Strickland-Cohen, Dr. Huddleston, Dr. Huckaby, Dr. Quin, Dr. Lindo, Dr. Switzer, Dr. Kyzar, Dr. Lacina

Others (Graduate Research Assistants): Cassidy Booe, Ying Wang, Ana Victoria Guardia, Yoon Hoo Lee; Amanda McCrossen, Jordan MacAskill, Taylor White, Hannah Parker, Perri Hockema, Miranda Otis, Abby Paul, Beau Hartweg

What is the purpose of the research? You are being asked to take part in a research project that will investigate the processes by which pre-service teachers grow professionally and the conditions that support and promote this growth.

How many people will participate in this study? Approximately 200 students each year

What is my involvement for participating in this study? If you agree to participate, you only agree that your education class work may be used as part of the data collected for the study. You will participate in all requirements of the normal course work whether you agree or do not agree to allow your work to be used as research data. The assignments are part of the courses and must be completed. Reporting of all findings will be done without names.

How long am I expected to be in this study for and how much of my time is required? You are asked to spend only the amount of time you would normally use for your education class work. This research project will continue for six semesters and your first year teaching. However, you will be asked to sign a consent document each term, allowing you to determine each term whether you want to continue in the research.

What are the risks of participating in this study and how will they be minimized?
Minimum risk has been identified for making the data available for this study. Emotional risks may include concern over having work examined by the researchers. The physical risks associated with this project are similar to those found in any teacher preparation program (for example: travel to off campus

locations or physical contact from students). All activities are typical of the usual methods course offered within the College of Education at most universities.

What are the benefits for participating in this study? There are no immediate personal benefits. If you choose to participate, you will could help us understand more fully how the teacher preparation program affects pre-service teachers and which components of the program are most helpful for pre-service teachers.

Will I be compensated for participating in this study? No

What is an alternate procedure(s) that I can choose instead of participating in this study? None

How will my confidentiality be protected? All information will be kept confidential. Your name will be replaced with a code or pseudonym and will not appear on any study documents. All data will be kept in locked files in the research office of the College of Education faculty. Analysis of data for research purposes will not occur until after grades have been issued for the term.

Some class sessions will be video recorded and many group discussions will be audio recorded. These recordings will be filed electronically in the TCU network with protections for limited access.

Is my participation voluntary? This research project is voluntary and you may choose not to have your work/data included without penalty. You may also decide to withdraw at any time without any penalty. NONE of your grades in any of the courses will be affected by your decision to consent or not.

Can I stop taking part in this research? Yes

What are the procedures for withdrawal? You may contact any of your education professors and ask to withdraw.

Will I be given a copy of the consent document to keep? Yes

Who should I contact if I have questions regarding the study? Dr. Molly Weinburgh, Principal Investigator, College of Education, 817-257-6115 or m.weinburgh@tcu.edu

Who should I contact if I have concerns regarding my rights as a study participant?
Dr. Dennis Cheek, Chair, TCU Institutional Review Board, Phone 817 257-6741.
Dr. Bonnie Melhart, TCU Research Integrity Office, Telephone 817-257-7104.

Your signature below indicates that you have read or been read the information provided above, you have received answers to all of your questions and have been told who to call if you have any more questions, you have freely decided to participate in this research, and you understand that you are not giving up any of your legal rights.

Participant Name (please print): ____
Participant Signature: ______________________________ **Date:_____________**
Investigator Name (please print): Molly Weinburgh **Date:_____________**
Investigator Signature: ______________________________ **Date:_____________**

Appendix B

TEXAS CHRISTIAN UNIVERSITY
Media Recording Release Form

Title of Research:

Education Majors Research Project - 2014-2019
Experiences of participants in a live-interactive planetarium program

Study Investigators: Dr. Weinburgh, Beau Hartweg

Record types. As part of this study, the following types of media records will be made of you during your participation in the research:

- Photographic Image
- Video Recording
- Audio Recording

Record uses. Please indicate what uses of the media records listed above you are willing to permit by initialing below and signing the form at the end. We will only use the media records in ways that you agree to.

- The media record(s) can be studied by the research team for use in this research project.

- The media records(s) and/or their transcriptions can be used for scientific or scholarly publications.
- The media records(s) and/or their transcriptions can be used at scholarly conferences, meeting, or workshops.
- The media records(s) and/or their transcriptions can be used in classrooms.

    Please initial: ______

I have read the above descriptions and give my consent for the use of the media recordings as indicated by my initials above.

Name: ______________________________

Signature: ______________________________ Date: ______________________________

If you have concerns regarding your rights as a study participant, contact Dr. Dennis Cheek, Chair, TCU Institutional Review Board, Phone 817 257-6741 or Dr. Bonnie Melhart, TCU Research Integrity Officer, Phone 817-257-7104.

Appendix C

Questionnaire

1. Name
2. Have you been in a planetarium before?
    a. If so, describe what your experience was like.
    b. If not, what would you expect from a planetarium?
3. Describe any prior experiences you’ve had regarding astronomy/space science.

Appendix D

Reflection Journal Prompt:

Reflect on your time in the portable planetarium during class. Jot down any ideas you have about your experience. Examples can include (but are not limited to) your feelings, emotions, what the program made you think about, what you learned, how your time in the planetarium may influence you in the future, and other ideas. Your responses can be, but do not have to be, in narrative form, or even text-based. They may also include illustrations and/or other forms of expression that can convey your ideas.

Appendix E

Interview Questions

1. Welcome. **Thank** participant for agreeing to the interview.
2. Ask the interviewee if you can record the interview.
3. When you are ready to begin, **turn on the tape recorder**. [Check if red light is on.]

4. Explain that you have a few questions you wish to ask about their views of planetarium education. You may wish to say something along the lines of, "**As we talk, I will be taking notes just to help me remember what you say. Sometimes I may ask you to expand on your answers. This will just help me make sure I understand your points. If you do not wish to answer the question, you can simply say, 'I do not want to answer that one.'"**

Themes: Experience

1) What are your thoughts about attending a class in a portable planetarium?
2) How would you describe your experience in the planetarium?
    a. Have you had any other kinds of experiences similar to this? (Is it like a movie/IMAX, museum? How does it compare?)
3) How would you describe the visual presentation?
4) How would you describe the presentation of content from the instructor?
5) What other factors, if any, had an impact on your experience in the planetarium?

Theme: Participation

1) What types of things did you see/observe in the planetarium?
2) In what ways, if any, did you interact with the presentation in the planetarium?
3) How did you feel about participating in an interactive planetarium program?

Theme: Connections

1) Were there any concepts, ideas, or content as a result of the planetarium program that stood out to you?
2) How do these concepts/ideas/content relate, if at all, to anything you have experienced in the past?
3) How do you think these concepts/ideas/content might influence your thinking or actions in the future?

Is there anything else you would like to share?

Thank you for your time.

Appendix F

Pilot Questionnaire

1. Name
2. How comfortable are you teaching astronomy/space science content?
3. Have you been in a planetarium before? If so, describe what your experience was like. If not, what would you expect from a planetarium experience?
4. Is space science content part of your curriculum? If so, what concepts do you teach, and how do you teach them?
5. What information do you know about the upcoming eclipse, and safe viewing procedures?
6. Are you planning on using the eclipse as a teaching opportunity? If so, please describe your plans.

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VITA

Personal Background	Beau Baxter Hartweg Bedford, Texas
Education	Diploma, Colleyville Heritage High School, Colleyville, TX, 2001 Bachelor of Science, Social Work, Texas Christian University, Fort Worth, 2005 Master of Education, Curriculum and Instruction in Science Education, University of Texas at Arlington, 2011 Doctor of Philosophy, Science Education, Texas Christian University, 2018
Experience	Teacher, Colleyville Heritage High School, 2008-2012 School Partnership Coordinator/ Educator, Perot Museum of Nature and Science, 2012-2017 Graduate Research Assistant/Instructor, Texas Christian University, 2014-present Intern, Noble Planetarium, Fort Worth Museum of Science and History, 2016 Planetarium Consultant, Frontiers of Flight Museum, 2017
Professional Memberships	Association for Science Teacher Education, 2014-present Southwest Regional Association for Science Teacher Education, 2014-present School Science and Mathematics Association, 2015-present South-Western Association of Planetarians, 2016-present

ABSTRACT

A CASE STUDY EXPLORING THE EXPERIENCES OF PRESERVICE TEACHERS IN A LIVE-INTERACTIVE PORTABLE PLANETARIUM PROGRAM

by Beau Baxter Hartweg, Ph.D., 2018
College of Education
Texas Christian University

Dissertation Advisor: Molly Weinburgh, Piper Professor and William L. & Betty F. Adams Chair of Education, and Director of the Andrews Institute of Mathematics and Science Education

The purpose of this qualitative case study research was to understand the experiences of preservice teachers who participated in a live-interactive portable planetarium program that used a simulated immersive visual environment. To that end, the study used a Deweyan theoretical framework to specifically look at the ways preservice teachers participated in and interacted with the planetarium; how they described their experiences; what connections to outside events or experiences could they make after participating in the program; and in what ways were their experiences were educative, miseducative, or noneducative. Data collection methods included a pre-questionnaire, video recording of the planetarium program, written participant reflection responses, and interview questions. The findings showed that students interacted with the planetarium program in a variety of ways, including through questioning, kinesthetic activity, observation, making predictions, choosing the focus of content, and social communications with peers. Participant descriptions of their experiences included comments regarding novelty, technology, visuals, and physical space. The connections participants made between the planetarium lesson and outside events and experiences were largely unique to each person, and included personal family connections, real world observations, remembering related scenes from a movie, prior visits to planetariums, and classroom exposure. The data showed that the majority

of experiences were educative, and were related to astronomy content, interactive activities, personal observations, sharing information, environmental responsibility, and future teaching practices. Some examples of miseducative experiences related to astronomy content emerged from the data, and there were no examples of noneducative experiences. The findings have implications for preservice teacher education and planetarium education communities.