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DESIGNING FOR IMMERSIVE TECHNOLOGY: INTEGRATING ART AND STEM LEARNING

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DESIGNING FOR IMMERSIVE TECHNOLOGY: INTEGRATING ART AND STEM LEARNING

By

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THESIS

Submitted in Partial Fulfillment of the Requirements for the Degree of

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Thesis Committee
Dr. Karla Kingsley (committee member)
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INTEGRATING ART AND STEM LEARNING

by

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B.A., Studio Art, University of Colorado, 2010
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ABSTRACT

Students struggle to learn STEM concepts. The arts have been proposed as a means to engage students in STEM education, resulting in the idea of STEAM. However, STEAM approaches do not always result in learning.

A collaboration between a major research university and a small Native arts college in the southwestern United States provided an opportunity for studying the potential for arts to engage students in STEM learning. This study investigates how participating art students (N = 4) solved technological and design production problems when working with immersive technologies in a paid summer internship program. The internship program lasted six weeks during the summer of 2013. Students were asked to create Public Service Announcements (PSAs) on the topic of water sustainability for the immersive digital dome. Students applied their prior film and digital media production skills as well as immersive media production techniques acquired through their participation in the summer internship program to create PSAs.
Qualitative data collected by the researcher, included interviews, observations, artifacts of student work and reflections. Qualitative and aesthetic analysis focused on finding connections between students’ personal connections and how that influenced their engagement in STEM and Art learning while designing for immersive technologies.

The research is important evidence of collaboration, creativity, communication and critical thinking as outlined by the Framework for 21st Century Learning, that also integrates STEM and the arts. The study contributes to what is known about how people learn when they design for immersive media, and identifies potential barriers and affordances for STEAM learning.
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CHAPTER ONE: INTRODUCTION

Rationale

Innovation is a driving factor in our economy and our ability to solve grand challenges; the complex problems facing the 21st century society, like energy, climate change and global health, which will depend upon the integrated, interdisciplinary solutions of our future generations (Elrod, 2010). Thus developing innovation should be central to the education of our students, especially in science, technology, engineering and mathematics (STEM) fields. STEM education should prepare students to confront the challenges of the 21st century by equipping them with a broader understanding of technology and engineering; these disciplines expand students’ ability to solve problems and be innovative (Bybee, 2010).

However, on a recent international assessment, the U.S. ranked 28th in math literacy, and 24th in science, adding to growing concern that the U.S. is not preparing its students to be innovative because they lack basic STEM skills and knowledge (Kuenzi, 2008; National Academy of Sciences, 2005). Innovation is essential to our nations’ success, but how do we teach students to be innovators?

Simply learning about technology does not support innovation; instead learning creativity and innovation through technology supports the development of innovation (Vaidyanathan, 2012). Kariuki (2010) suggested art may improve STEM learning. The arts are also suggested to evolve skills in critical thinking (Burton, Horowitz, & Abeles, 2000; Catterall, Dumais, & Hampden-Thompson, 2012; Lampert, 2006; Milkova, Crossman, Wiles, & Allen, 2013), which are important in STEM fields.

Creating a solution of cultural or societal significance places an aesthetic value on the innovation. The design process integrates aesthetics in the process of problem identification and risk assessment and material selection for solving challenges; it requires prototyping, testing and evaluating design usefulness (Bequette & Bequette, 2012), for proper development of a successful design. Developing “intelligent visual literacy” involves the critical consciousness and knowledge of aesthetics, which Dewey (Nakamura, 2009) suggested is transferable to a variety of creative endeavors.
However, it is apparent there is a discrepancy between how we value the arts and STEM when we compare the budgets of the National Science Foundation and the National Endowment of the Arts (Ghanbari, 2014). Likewise, while schools in the US require mathematics, and at least middle and high schools require science, few require arts course work (Ghanbari, 2014).

Many students today are not well motivated in traditional education settings because they don't see the connection between their experiences and future careers. There is now conclusive evidence suggesting that students—including those traditionally underrepresented in STEM fields—find relevant connections to their own learning when engaged in active, learner-centered instruction (Elrod, 2010). Students need to be able to draw on their personal and formal educational experiences, challenging worldviews and perspectives in safe learning environments where they can explore, inquire, test and practice applied design (Ramaley, 2009). Although compelling evidence has expanded our knowledge about how students learn (Narum, 2008; Schwartz & Bransford, 1998; Bransford, 1999), the broad use of connected, engaging and comprehensive learning environments that attract and retain diverse STEM graduates has not yet been achieved (Elrod, 2010); the diversity gap in STEM is still not closing.

One approach that has been suggested recently is incorporating arts into STEM education—termed STEAM. I define STEAM education as an integrated approach to teaching science, technology, engineering, art and mathematics, where each discipline receives equal attention. Based on this definition, simply integrating science with art, or technology with art would not qualify as STEAM. This integrated approach appears to meet many of the challenges described above. However, the integration of these subjects is difficult (Sochacka, Guyotte, Walther, Constantino, & Kellam, 2013) suggesting that STEAM could marginalize in-depth STEM learning (Ghanbari, 2014).

**Statement of Problem**

Implementing STEAM effectively has proven difficult. One challenge educators face is the need to be careful not to *STEAMwash* their programs—brushing over STEM concepts. It is critical for educators to make sure students fully engage in STEM learning
through project-based art practice. STEAM learning should fully integrate science, technology, engineering, art and math, using project-based learning as a vehicle for integration of each subject. An educator should not pick a few subjects, for example, science and art and call the lesson STEAM, only when a lesson equally and fully integrates each subject should it be considered STEAM. The notion of integration of subjects is paramount for STEM education (Breiner, Harkness, Johnson & Koehler, 2012), which certainly applies to STEAM education too. STEAM achievement in higher education has not been established, and calls for further research may contribute to greater understanding and implementation of such learning programs (Ghanbari, 2014).

**Research Questions**

1. How might students in design teams solve design production problems using immersive technology as they create Public Service Announcements (PSAs)?

2. How might they adapt and apply specific knowledge from STEM and Arts to solve specific design problems together?

3. How does their aesthetic and expressive intention evolve over time as they solve design production problems?

4. How might they bring contemporary context and personal meanings to their PSAs?

**Conceptual Framework**

**Introduction to the digital fulldome**

The current study explores how students engaged in STEM and art learning when designing a Public Service Announcement (PSA) for the fulldome (Figure 1.1). The fulldome is a digital planetarium using several digital projectors. The immersive environment offers a technically challenging environment for students constructing fulldome media.

Immersive media comes with its own unique set of design problems, and because the technology is new and evolving, there is opportunity for innovation in solving these
design problems. The first and most obvious challenge for designers is the geometry and size of the dome projection surface—4,000 pixel diameter—and how to warp the images matching the geometry of the dome. Additionally, immersive designers need to consider the *sweet spot* of the dome, an area where the audience members’ eyes naturally come to rest. Lantz suggests the success of the projection is dependent on the ability of the designer to correctly edge-blend the images during production (Lantz, 1998). When transforming a two-dimensional viewing plane into a domed, convex viewing plane, edge blending becomes a difficult task as geometric mapping is essential in the successful transformation (Lantz, 1998). In this study, both domes have six projectors that creators are capable of seamlessly stitching images in the dome creating an immersive feeling for the viewer as the image wraps around them in 360 degrees. This effect is created by the physical curvature of the dome and correctly projected images.

The projection map is complex and must be adjusted correctly for the fulldome to have an immersive effect. If the eyes see an error in the projection map, then the person will not believe the environment to be real. Figure 1.2 shows the way in which the six projectors are oriented inside the dome, to cover the surface of the fulldome screen.
Figure 1.2 Projector map inside fulldome during a projector identity test for each projector, inside the fulldome. The image was taken during the initial phase of dome calibration.

Figure 1.3 below shows the geometric layout of the dome during calibration. This is an essential part of the domes’ projection mapping features and must be correct for the images to be projected with normal parallax. The parallax allows for the projection to be seamless and for lines to appear straight despite the curved format of the fulldome. For example, trees should appear to stand up straight, not curve over the top of the dome.
Figure 1.3 Geometric view of fulldome during calibration. One dome master is not quite aligned with the other; hence one circle is more oval in shape. This process is how media are presented naturally in the fulldome. If these calibrations are off, then the images will not look correctly stitched in the dome projection despite an accurately produced dome master.

A dome master is the mask and basic format for creating media for the fulldome (Figure 1.4). The gray area indicates the area in which the audience’s eyes naturally come to rest in the fulldome when seated in the dome theater with unidirectional seating. This image also exhibits the most basic feature of the dome master template, the circular mask. The mask must be present during the entire film regardless of whether the media is zooming in, out or moving. The top of the circle is content that will be projected directly behind the audience in a fulldome, while content in the lower area of the circle will be projected front and center in the dome, in what is considered the sweet spot. The entire edge of the circular dome master will be projected onto the edge of the dome surface at the horizon.
Creating media for the fulldome involves creating spherical photography, which is a process of exposing images in every direction from a nodal center of the camera, which allows the photographer to expose images 360° by 360°. The photographer then stitches the sequence of 170 plus photos together to build a rectilinear panorama that represents the atmospheric and/or environmental photo. Figure 1.5 below is an example of a rectilinear photograph.
Figure 1.5 Example rectilinear panorama of Cerro de la Virgin archaeology site imaged by Jane Crayton in Oaxaca, Mexico.
To use this rectilinear photograph as a backdrop in fulldome media, a Mayasphere must be created (Figure 1.6), which is a three dimensional sphere. The rectilinear photograph is mapped to the inside surface of the sphere using Autodesk's 3D modeling software, Maya. The spherical photograph is applied as a texture to the inside of the sphere and viewed from the inside of the sphere using a virtual camera. This design process supports the correct parallax and aesthetics for projecting the spherical photograph in the fulldome. The designer can control the environment of the fulldome using a variety of media including rectilinear panoramas, 3D objects, virtual camera rendering and recording and scripting for animation as well as a plethora of other multi-media tools.

These problems are inherent to the immersive digital dome. They have no pre-defined solutions and thus require innovation. Understanding how students use available design tools is essential for building effective immersive media design programs that engage students in STEM and art learning. This study is informed by research on:

1. the nature of fulldome immersive technology design problems;
2. personal relevance and how it might influence participation;

3. multidisciplinary design, integrated and holistic approaches to learning, like STEAM, and how these approaches prepare students to solve real-world problems; and

4. authentic approaches to instruction, like project-based learning, and the role that authenticity plays in learning.

The nature of immersive technology design problems The process of designing digital media for fulldome immersive technology involves advanced and emergent uses of planetarium technology; it requires the designer to be innovative in his/her use of engineering and media to solve *ill-structured problems* of the immersive environment. *Ill-structured problems* are problems that are poorly defined; they have no single correct answer, are open-ended and unpredictable (Jonassen, 2000). Dorst (2006) sees ill-structured problems as the core of problem solving activity, partly because the problem solver’s prior knowledge influences how he or she interprets the problem. Designing engages students in a process of using technical skills while also attending to aesthetics, social and cultural issues (Vande Zande, 2007). Thus, immersive technology design problems require students to apply their prior knowledge and experience to immersive media design.

**Personal relevance and how it might influence participation**

Because they draw upon prior experiences, students might also find a personal connection to the design. In this study, I link students’ personal relevance to their participation and completion of the digital media project. Lazaros and Bormann (2013) argue that students who are personally connected to a project or activity are more likely to be intellectually engaged with it. This study explores how students tap into their personal or collective experiences, and how that might have motivated them to build their PSA narratives. In this study, the teams consist of students with diverse design skills; the diversity of each student’s interests in a design group can make it difficult to identify which activities are personally meaningful.
Integrated and holistic approaches to learning and how these approaches prepare students to solve real-world problems

STEAM involves the integration of multiple disciplines, equally. This can be a challenge, yet advocates of STEAM and similar approaches argue that these approaches better prepare students for real world problem solving. According to Fleischmann and Daniel (2013), designers are faced with increasingly complex technologies that involve a variety of skills and knowledge that require extensive use of hard and software, which can easily overwhelm students in design programs. Instead of laboriously teaching each student to use every technology, Fleischmann and Daniel suggest that multidisciplinary design teams better prepare students to work in the design industry because this approach mimics the professional work environment of designers in which individuals use their expert areas to seek solutions collectively.

When students participate in applied research projects, they can solve problems and find practical solutions to complex problems. Foroudastan and Hardymon (2003) maintain that students participating in partnerships with industry learn to design and explore practical skills and technologies that meet real world issues.

The role authenticity plays in learning

Interaction in multidisciplinary design teams can stimulate authentic problem solving and product development experiences for students working collaboratively to solve complex problems (Fleischmann & Daniel, 2013). The authenticity of a project and how deeply it is connected to a relevant industry can contribute to the technical quality of digital media designed by fulldome production students.

One approach to creating an authentic learning environment is through project-based learning (PBL). Such approaches typically present “students with a variety of dilemmas and issues in contexts and scenarios that are capable of solution through design” (Dolowala, Thompson, & Toner, 2011, p.418). Authentic PBL learning prepares students for industry and workplace problem solving (Dolowala, Thompson, & Toner, 2011). Edelson, Gordin, and Pea (1999) argue more authentic PBL learning experiences can motivate students.
Significance of Study

Art educators can support the development of students’ critical thinking skills using project-based learning. They can support the development of students’ creative voices, promoting individual student growth from their participation in design projects. Understanding how project-based art can serve as a vehicle for STEM learning could help educators construct learning environments that foster 21st century goals to teach productive creativity and innovation (Sawyer, 2006). Additionally, artists approach problems with an eye toward metaphoric meaning and making.

Scope and Delimitation

Limitations of the IRB-approved research protocol did not cover students from the Native American Arts College (a pseudonym) who participated in the internship; therefore, I was unable to collect data from them about their participation. While there are many interesting questions that one might explore about the role of culture in learning, this study was limited to the points of view of only half the students. The scope of this study is delimited to focus on understanding two cases of STEAM learning. This study does not deeply explore areas such as cultural relevance in aesthetic decision making, personal relevance through cultural identity and multicultural collaboration.
CHAPTER TWO: LITERATURE REVIEW

Overview

The purpose of this literature review is to connect diverse literature on how designing for immersive technology might engage STEM and art learning in an integrated fashion. In particular, I focus on how teams—with diverse skills—designing for immersive fulldome can create opportunities for learning. I connect project-based learning and authentic, ill-structured problem solving to personal relevance and motivation. I examine studies focused on project-based learning, ill-structured problem solving, authentic learning and personal relevance.

Project-based learning supports students to learn through ill-structured problem solving

Project-based learning (PBL) is a teaching method in which students learn by working to solve problems over several weeks of instruction. PBL has developed into a robust method for delivering content and real-world experience to students, supporting real problem solving. Singer and colleagues (2000) explain when students engage in active, in-depth inquiry by collecting and analyzing data, they acquire the skills necessary to understand and communicate their results. Solving problems is one of the most important skills students need to prepare them for success in their professional lives (Jonassen, 2000). When students develop the skills to question, hypothesize, investigate and develop conclusions based on collected evidence, they expand their problem-solving and critical thinking skills for the 21st Century workforce (National Research Council, 2000).

Geier and colleagues (2008) conducted a study to examine how student participation in project-based science might improve student achievement on statewide assessments. Seventh and eighth grade students participated in project-based learning activities, designed as a series of 8 to 10 week units. The three units were designed as inquiry investigations with driving questions that led students to create artifacts that demonstrated student understanding. Using the Michigan Education Assessment Program (MEAP) statewide standardized test as a measure for the success of the program, they
found that participating students had higher MEAP test scores compared with those students who did not participate in the study. Students who participated in both 7th and 8th grade had the greatest gains in test scores with an average of 66 MEAP points over non-participating students. The study highlights the significant gains in learning to which PBL can lead.

In another study, investigators studied the impact of inquiry-based science instruction on culturally diverse elementary students (Cuevas, Lee, Hart, & Deaktor, 2005). Although the authors refer to instruction as inquiry-based, the instruction shared a great deal with project-based learning. Third and fourth grade students participated in a multi-year study that took place in a large urban school district with diverse students for whom English was often a second language. A variety of evidence was collected including pre and post audio, video elicitations, tests and student artifacts, which were coded using specific rubrics. The study showed that students improved significantly in their ability to develop procedures for problem solving. Their ability to formulate hypotheses relevant to the proposed questions increased with their understanding of the problem. The students significantly increased in their ability to develop procedures for collecting and analyzing data as well as formulating conclusions. The study demonstrates the positive impact of inquiry-based science instruction for diverse cultural groups.

Together, these studies suggest that project-based learning can be an effective way to develop understanding and skills in culturally diverse populations.

The nature of ill-structured problem solving

The problems in PBL are typically *ill-structured*, meaning they are emergent and unpredictable, unlike well-structured problems that are well defined with clear goals and a constrained set of variables (Jonassen, 2000). With ill-structured problems, the solutions are not always clear until the problem is fully understood and solved. When a problem solver introduces new resources in an effort to solve the problem, changing the problem space, a well-structured problem may transform into an ill-structured problem (Simon, 1973). When a problem has real consequences that cannot be reversed, and the problem space changes with greater understanding of the problem, it is considered ill-
structured (Simon, 1973). Such problems often require domain-specific skills (Jonassen, 2000). A difference between inexperienced and experienced designers is their ability to solve ill-structured problems, verses simply memorizing algorithmic solutions to problems (Siegel & Stolterman, 2008).

Students can develop higher order thinking skills by solving ill-structured problems that they investigate in real-life situations (Costantino, 2002). In a study where students solved well-structured or ill-structured problems, the students who solved ill-structured problems outperformed their counterparts on a transfer task, even when they had initially failed to solve the problems (Kapur & Bielaczyc, 2012).

**Authenticity supports learning**

Authentic experiences and authenticity are important to humans. According to Wiggens and McTighe (2005) authentic learning experiences transform students from passive learners into active learners where they are able to construct expanded meaning. By participating in authentic real-world problem solving, students can develop skills used for scientific inquiry (Petrosino, 2004). For example, in a case study, astronomy students in a well-equipped technology classroom engaged in authentic, project-based inquiry over five weeks. The study conducted by Petrosino (2004) included 500 high schools around the US. Researchers collected instructor and student interviews, emails and artifacts (e.g., curricula guides, handouts, class projects and notes) for analysis. Students analyzed real images of astronomical phenomena, which they used in conjunction with imaging processing software developed for the Hands on Universe (HOU) curriculum. Students were able to communicate their questions and findings to real scientists and researchers. The students collaborated between themselves and with the researchers and scientists, providing them with real-world experience to tackle astronomical investigations. The students transformed their identities from students to scientists and took ownership over their learning experience.

**Personal relevance affects participation**

According to Costantino (2002), when students take on roles as stakeholders, they can find personal meaning in the problems they are solving. It has been suggested that
students who are permitted to work and investigate issues of real concern to them have
greater engagement in the learning process (Gude, 2007). Interest is paramount to how
one processes the importance of information; thus, how compelling the task is can
influence learning (Hidi, 1990). In this study, I wish to elaborate on the connections
between students’ personal relevance and the compelling nature of media produced using
digital technologies.

Because he noted how visual culture education helped his students expand their
world views, Darts (2006) changed the direction of his curriculum, connecting it to his
students’ personal lives. Such personal connections can increase the student’s interest in
the subject. Darts explained how his students were earnestly committed to their learning
and the learning of their fellow students.

Experiences can increase students’ curiosity and drive, supporting them when
collaborative learning can foster a community of learners. In a study on sixth grade
science, using the jigsaw method, students become experts in one subtopic, then shared
their expertise with others in their group so every member learned from one another; their
interest and enthusiasm for learning increased because the students developed ownership
over their learning (Brown & Campione, 1998). This activity built a community of
learning because it required the group to articulate their shared knowledge.

In a design team with diverse skills, the knowledge and expertise are divided in
much the same way. Each student is responsible for a specific set of skills or expertise,
yet they need to communicate that knowledge to the group. The student’s personal
relevance to the project is supported, because they have a chance to share their expertise
with their peers.

**Art as a means to develop a socially engaged stance**

Art practice has the potential to help students develop a socially engaged stance.
Darts (2006) developed a curriculum to support the idea that art promotes the
development of an “ethic of care,” in turn supporting positive transformations for
students to affect their own lives, their communities and their worldview. Students need
to be prepared for twenty-first century problem solving by developing foundational skills in ethical reasoning, fostering personal, social and cultural responsibility (Elrod, 2010).

We need ethical and effective innovators, researchers and educators; if we do not educate students to make critical design decisions when innovating, their media could be ineffective or unethical. Vande Zande (2010) discussed how art can integrate with social activism as many designers confront social issues related to the environment, mass culture, and societal health. Rolling (2008) argues that art-making can be explained as a social practice that questions the traditional value of art objects, in favor of scrutinizing social semiotics.

Gude explains an idea presented by Richard Anderson in 1990: “Good multicultural curriculum introduces us to the generative themes of others—helping us to see the world through the eyes of others—understanding the meaning of artworks in terms of the complex aesthetic, social, and historical contexts out of which they emerge” (Gude 2007, p. 9). Campbell (2011) describes how empathy can be developed using holistic art education. A holistic approach includes social, moral and spiritual aspects, rather than the narrow focus common to classrooms. Campbell (2011) concludes that this holistic approach “provides the foundation for self-transformation, leading to a life of personal and communal responsibility” (p. 23).

Rolling (2008) suggests that arts-based techniques for constructing human data adequately and effectively are beautiful because they allow space for emotional connection to the information, illuminating and delivering understanding from a new perspective, instead of their beauty being simply based on their aesthetic allure and charm. He suggests beauty is associated with the insight of data, which informs and educates the human essence.

**STEAM and other integrated approaches to learning**

The Partnership for 21st Century Skills and other education organizations have outlined that students need to acquire expertise and philosophy of the arts in order to be successful in the global economy (Platz, 2008). Forecasts for the U.S. economy suggest that millions of professionals with STEAM skills, especially engineering and technology
will be needed in the next decade (Erickson, 2013). However, education has been focusing more on assessment of academic skills, with increasing neglect of many other aspects important for children's development (Campbell, 2011). Research demonstrates that students have significant gains academically when they have access to high-quality arts programs (Robinson, 2013).

Mayo (2007) suggests 21st century skills are essential for student success because students need to be able to understand, deconstruct and reconstruct their own worldview. She argues that students need the ability to navigate technology through the production of cyber arts. According to Shapiro (2010), critiques are crucial for art education and comparable to scientific peer review, supporting students' reflection and review of problems encountered during artistic production. Lowenfeld, (1975) describes that individuals and society benefit from applied use of creative thought, because art practice fosters critical thinking (Lampert, 2006). Reflective behavior promotes novel ideas and new perspectives, because the individual has developed a contextual mindfulness (Csikszentmihalyi & Hermanson, 1995). The future workforce will need to be self-reliant problems-solvers using critical thinking skills which drive innovation through proficiency of science, technology, engineering arts and mathematics subjects according to Erickson (2013).

Combining content from various disciplines can help students decipher the importance of science in everyday life (Shapiro, 2010). However, the importance of what STEM might be able to offer the arts, is almost always overlooked when highlighting the complicated integration of STEAM education (Sochacka et al., 2013). To solve some of the pressing issues facing humans, Crayton (2015) suggests art and diversity are essential for development of an ethically minded technologist who should be able to engage their creative and critical thinking skills. Robinson (2013) argues access to arts education for disadvantaged and minority students has diminished. Yet, the biggest hurdle for STEAM learning is the domain specific approach in traditional education (Sochacka et al., 2013). Thus the equal integration of science, technology, engineering, arts and mathematics to solve real-world problems is the most important concept of STEAM education (Breiner, Harkness, Johnson & Koehler, 2012; Labov, Reid, & Yamamoto, 2010; Sanders, 2009).
STEAM approaches prepare students for industry

Foroudastan and Hardymon (2003) suggest industry partnerships with educators provide students with access to industry-standard technology and allow students to gain experience in applied research projects. When educators create space for students to explore meaning as well as the production of art objects, they prepare students for the challenges of our global economy (Darts, 2006).

The POOL model, developed by Fleischmann (2008), involves a multidisciplinary pool of industry professionals who mentor a multidisciplinary pool of design students; this approach mimics professional design teams and situations found in industry. Fleischmann (2008) developed the POOL model as a framework to help manage design teams, responding to the increasing complexities and specialties of technology, design and communications. Fleischmann sought to support design students’ involvement in authentic problem-solving situations, which supported and reflected industry standards and practices (Fleischmann & Daniel, 2013). This was done in an attempt to solve issues where media students were overwhelmed with the vast amount of technical knowledge needed to complete industry standard designs. Instead, Fleishmann’s students had open opportunities to focus on their design specialties within the design team, nurturing their expertise in a particular design field, while also supporting their expanded interests and giving them experience developing skills in a variety of other disciplines (Fleischmann & Daniel, 2013). This type of learning environment is a positive and obtainable approach to learning STEM that should be considered by art educators interested in supporting diverse skilled design education or STEAM.

Risks to integrating subjects in STEAM

James and Marjorie Bequette (2012) caution educators about integrating subjects; they risk missing opportunities to engage important topics, like scientific evidence, aesthetic decision-making and historical contexts, resulting in the lesson paying lip service to those subjects. Additionally, stereotypes about the integration of arts and STEM, the contribution of each disciplines input need to be addressed, to avoid implied misconceptions about the arts and STEM (Sochacka et al., 2013). The best way for educators to avoid these pitfalls is for them to find real-world applications, placing the
lesson within a problem-based context. This supports the student by encouraging curiosity, experimentation, and opportunities to take risks without failure. Best practices by instructors would include arts integration learning activities and collaborative skills as a priority diverse cultural populations (Robinson, 2012). Purposeful design and inquiry is a critical piece for the integration of STEM education and combines technical design with scientific inquiry, positioned to solve technical problems (Sanders, 2009). However, successful integration of two or more subjects is a difficult task, requiring educators to have expertise in two or more disciplines, which requires exceptional educators or collaboration between discipline-based educators.

**Gaps identified**

Using design as an entry to STEM learning has only recently been researched. In this study, I draw conclusions about how immersive project-based art practice using fulldome technology has the potential to engage students in a variety of STEAM learning opportunities, providing a plethora of 21st century skill-building activities.

**Study Goals**

The purpose of this research is to explore how project-based media design using immersive technology may expand student opportunities in STEM related media fields. The case study will provide insights into how participants may or may not have used STEM concepts through participation in the immersive media internship. I will examine how educators may successfully teach design production for immersive technologies using project-based art. The case study is an inquiry about student design tools (software engineering and computer science) and tool implementation, specifically in regard to problem-solving skills.

Research goals are defined as below.

1. Create an initial understanding and context for immersive art and design education supporting STEM and Arts learning.

2. Develop an initial theoretical stance for how immersive art & design production may support STEM learning when using authentic project-based art inquiry.
CHAPTER THREE: METHODS

Qualitative Research

This is a case study using qualitative research methods, based on analyzing data using grounded theory and cross-case analysis. Qualitative research provides an opportunity to explore the phenomena of interest in an unpredictable environment. Humans are not easily quantified, especially when looking for socio-cognitive processes in multidisciplinary groups. According to Creswell and Plano Clark (2011) “rather than select a large number of people or sites, the qualitative researcher identifies and recruits a small number that will provide in-depth information about the central phenomenon or concept being explored in the study” (p. 174).

Qualitative research is distinguishable from other research approaches in that it allows researchers to influence theory and solve complex problems that are socially oriented. Mertens (1998) suggests qualitative research is used to support or contradict theory that reflects the phenomena of specific relationships or constructs, by connecting them to similar events. Qualitative researchers collect, analyze and interpret using systematic methods of inquiry. This qualitative study involves case study, including cross-case analysis and is guided by grounded theory.

Case study allows the researcher to design a theme-based hypothesis based on the development of a social phenomena by outlining a process for review and comparison of results to hypothesis (Bitektine, 2008). Qualitative analysis can be completed using pattern-matching techniques (Campbell, 2011; Trochim, 1989) where theoretical abstractions can be compared to data and evidence that surface through what is known as grounded theory research (O’Connor, Netting, & Thomas, 2008). In grounded theory, data collected during the study inform the hypothesis (Smith-Sebasto & Walker, 2005; Glaser, 1967).

The purpose of a case study is to provide an intensive, in-depth focus on a specific and bounded situation or phenomenon involving a program, event, process or one or
more individuals. Case studies contribute knowledge and understanding of a specific phenomenon through the act of inquiry (Glesne, 2011). According to Mertens (1998), "the more the object of study is a specific, unique, bounded system," the greater rationale for calling it a case study (p. 445).

According to Mertens (1998), theory development is a critical piece of the design phase where the researcher will first develop research questions and then identify the propositions and hypothesis relevant to the study. Then the researchers’ task is to clarify the unit of analysis and establish logic by linking data to theory. The criteria for interpreting data should be explained with comparisons and contradictions to rival propositions and hypothesis (Mertens, 1998).

A case study is not a method, methodology or research design, but rather a heuristic that involves a detailed portrait of a phenomenon (VanWynsberghe & Khan, 2007). Klenke (2008) explains the term heuristic implies a case of study that engages analytic induction to resolve the case, which guides the researcher’s attention toward inquiry, problem solving and modeling. No single discipline has the monopoly on case study and multiple disciplines may contribute. This further suggests that case studies may be employed within a variety of paradigms, like constructivism, interpretivism, or pragmatism (Yin, 2009).

The case study is not about the case uncovered, but more importantly about the unit of analysis constructed and employed (Klenke, 2008). Case studies are subject to time and place for analysis of specific social phenomena; they can be theoretical or empirical (Ragin & Becker, 1992). The goal of case study research is to critically analyze the data in an effort to validate the theoretical contribution (Mertens, 1998).

The quality of the research is subject to the construct, internal and external validity as well as the ability to replicate the study later (Yin, 2009). The researcher is urged to collect multiple sources of evidence to strengthen the case including researcher documentation, interviews, observations and artifacts. The data are organized, read, and coded to help the researcher decipher themes, (Creswell, 2009; Creswell & Plano Clark, 2011). This approach helps the researcher build interpretations and meanings, integrating
the themes and descriptions about the phenomenon studied. The case is written up in a
descriptive, story-like construction, which aids the reader to understand the real-world
context surrounding the situation of the case.

The case should then be compared and contrasted against several other case
studies and peer-reviewed publications supporting or contradicting the findings of the
case, establishing a chain of evidence as suggested by Yin (2009). Contrasting and
supporting evidence should be included in the case study, highlighting how to expand and
grow on the previous inquiries, and providing insights into future investigations. This
approach to case study supports the researcher in suggesting scope-appropriate
predictions after careful description and portrayal of the phenomenon studied.

**Grounded theory**

The purpose of grounded theory is to generate theory using comparative analysis.
From evidence theory is uncovered as conceptual categories emerge and are used to
support the theoretical concept (Glaser, 1967). Data collection and analysis happen
simultaneously, guiding the researchers’ theoretical development (Corbin, 1990).

This type of analysis can be completed using pattern-matching techniques
(Campbell, 2011; Trochim, 1989) where theoretical abstractions are tested through
comparative analysis between data and evidence that surfaced through analysis
(O’Connor et al., 2008). Grounded theory defines phenomenological conditions found in
specific sets of data (Corbin, 1990).

In a case study conducted by Youssef and Berry (2012), interdisciplinary design
teams participated in an authentic design project where they were introduced to new
computational design environments using industry-standard tools. The study investigated
how students participating in the class learned to think spatially. The researchers used
grounded theory to generate conceptual categories from evidence. For example, since the
students appeared highly motivated, they chose to code motivation; further coding
showed motivation might have been a result of students perceiving authenticity of the
project. The teams ultimately designed products that exceeded expectations of the
instructors and researchers, which seems to correlate to evidence found in project-based learning.

In another example of a case study by Smith-Sebsto and Walker (2005), students’ perceptions of a residential environmental education program were studied. The case involved documenting observations and collecting data from students. The researchers interviewed the students and transcribed the interviews. The data were organized into broad categories and coded, with codes emergent from the data. These were compared and contrasted to find connections supporting the case by helping formulate the hypothesis about the emergent codes. Their analysis revealed that student's safety and social well-being needs were prioritized above scientific or recreational education. They found that a learner-centered instructional mode—instead of an educator-driven top-down approach—would be better received by students in the program.

Both examples described above used qualitative methods for data collection and grounded theory methods for analysis. Both cases investigated how to expand student knowledge in STEM, and resulted in findings about how students' motivation for learning in authentic learning environments might be enhanced. The goal of the current study is to gain a greater understanding of how to teach design for immersive technology, integrating art and STEM learning. The methods employed are a combination of qualitative methods for data collection and grounded theory approaches for analysis of data.

**Setting**

A collaboration between Southwestern Research University (SRU, a pseudonym) and the small Native American Arts College (NAAC, a pseudonym) allowed eight students to participate in a six week (May–July 03) paid internship program. Half of the internship took place at NAAC and half at SRU. Both NAAC and SRU had computer labs and fulldomes.

**Participants**
University undergraduate students from a variety of art disciplines were recruited to participate in the internship; specifically, those with experience in at least one of these areas were recruited: photography (panoramic &/or high-dynamic range (HDR) experience a plus); cinematography and editing; 3D modeling and animation (camera mapping and virtual set development a plus); compositing and color grading; and, graphic design and motion graphics. Four students from SRU were selected from a pool of applicants, and all four consented to participate in the study. Consent was not sought from NAAC students. The students worked in teams of four, with two students from SRU and two from NAAC. Only those who provided consent are included in the study (Table 3.1). Two case studies are reported in this study; each case includes two consented students. One case, Team Rainwater Station, focused more consistently on finding and incorporating science concepts into their design; in contrast, Team We are Water used art to communicate their ideas about culture and ethics.

Cross case study design

<table>
<thead>
<tr>
<th>Case</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team Rainwater Station</td>
<td>n = 2 students, Connor and Mark (pseudonyms)</td>
</tr>
<tr>
<td>Team We are Water</td>
<td>n = 2 students, Juan and Stewart (Juan dropped out in week three)</td>
</tr>
</tbody>
</table>

Materials

The summer internship focused on learning advanced production techniques and creating unique public service announcements for the full-dome industry. The interns learned to create immersive media for the fulldome multi-projection environment.

The internship began with an internship schedule (Appendix A) and project launch document, in which the interns were asked to create a Public Service Announcement for the fulldome.
Dear Sir or Madam:

We would like to invite you to create two fulldome Public Service Announcements, which discuss water conservation and sustainability. Public Service Announcements play a vital role in educating the public on sensitive topics. It is hard to produce these types of announcements, because it is costly, and often engages sensitive political issues.

However, this is a unique opportunity for science museums and others to help inform the public about important plans, technologies, laws in water conservation and other issues involving sustainability. It needs to be done with grace, tact and without preaching. They need to be beautiful and informational and address a problem with people, science, technology and engineering as the innovative driver for solving these problems.

Last year at the IMERSA Summit, we had a lot of great students attend the summit, so we thought this might be a good way to keep them engaged for next year. We would love to have these PSAs presented at the next IMERSA Summit.

We thought we would reach out to The Summer Internship program at the NAAC and SRU and see if their students may be interested in creating these most important type of messages, which could be shown between scheduled feature presentations at museums internationally.

It would be very important the PSAs speak to the scientific and k-12 communities as well as the general public (informal science learning) models embraced. They need to be professional, and presented from a scientific point of view, enhancing STEM education in any way possible.
Constraints: (Choose One)
1. Macro/Micro
2. Black & White w/ (color) highlight
3. Chroma or Luma
4. Mapping
5. Green Screen

Requirements
1. Two 30-90 seconds water sustainability PSAs
2. 4k fulldome format
3. Rated G or PG
4. Include spherical images, video, animation, narration/voice, surround sound
5. Distribution master preview ready by Monday July 1st 5 pm
6. Delivery of 2 PSASs at NAAC July 3rd 5 pm and upload to FDDB/IMERSA

The project launch document invited the students to create these short immersive media projects for science museums to be debuted at a prestigious fulldome summit. The document was formatted as an official letter and described how science museums in general cannot create politically oriented content, such as PSAs on water sustainability. The letter invited the students to fill this conservation media gap for public programming at museum fulldomes. The document described the context in which the PSAs should approach the subject of water conservation, and instructed the students to include any relevant STEM content as well as complete the technical requirements from the project launch document in their design.

Instruction
The internship schedule (Appendix A) was designed to provide the students with an intensive series of workshops in immersive media production technologies. Each day, part of the internship was spent learning new technologies or skills for immersive media
then the second half of the day, students spent applying the newly acquired techniques to produce fulldome media. Each of the three instructors taught their specialty or area of interest during the immersive media production internship. Students were assigned readings for the first three weeks of the internship to broaden their knowledge in immersive media production. The second half of the internship focused on the production of their immersive PSA productions. They used the entire day for the last three weeks to complete the project from the launch document. Students managed their own time, with instructors monitoring and mentoring students.

During the first week of the internship, the instructors introduced the students to brainstorming techniques for building their narratives. Students participating in the internship were divided into design groups where they were preselected to work together and have complementary skills. We encouraged them to also take lead roles in their positions to help guide the project for successful production of a Public Service Announcements (PSA) for the digital fulldome. The students were presented with a brainstorming activity after discussing the methods and concepts of brainstorming in groups and how they might record their ideas.

The students were instructed to work together for several hours to complete the brainstorming activity and produce a document with a list of ideas for their PSA narratives. The students had to also work within the framework of the project launch document, brainstorming ways to integrate the themes and requirements of the document into their narratives. The document collected from the students (Appendix E) after the activity shows a list of ideas they constructed from the brainstorming activity for their PSA.

**Data sources**

Data collected included copies of student work, surveys, interviews with students, and researcher journal reflections. Student work included a range of data types and was collected to document the design progress. Production events were photographed and screen shots of their work in progress during post-production were collected. All emails, and artifacts from the classes, including scraps of paper the students may have discarded,
with scratched ideas, or sketches for production plans were collected and scanned. Student versions of media created for their PSA videos were archived in the database as project artifacts.

**Surveys**

The few surveys that were administered were designed to inform the research about the students’ prior and current knowledge surrounding immersive media, their learning experience during specific activities or their opinions and reflections on activities and how they connect personally to them. For instance, questions included the following:

- How would you describe your group’s brainstorming process and your participation in this activity?
- How might your personal experiences, histories or connections reflect on your project.
- What skills did you learn last week?

The short surveys were a page or two in length. They contained only a few open-ended questions or items. Responses varied from 1 to 10 sentences per answer.

**Interviews**

Exit internship reflective 1-page surveys were given to the students who participated in the interview process. Many of these questions asked students to rate their experience:

- How personally relevant was the project?
  Level of Personal Relevance 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10
- Did that level of authenticity affect the technical quality? Yes / NO
  Level of Technical Quality 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10
Students were interviewed over a year later. Interviews were conducted at the convenience of the students. Interviews were conducted at the SRU where the students could review the final versions of the PSAs. Interviews lasted about an hour. Interviews were audio recorded and transcribed. Each student was asked the same questions (Appendix D):

- Was the project authentic?
- How did you start the project?
- How did you come up with ideas?
- Tell me about your team, and what it was like working in a multidisciplinary design team?

**Researcher journal reflections**

Daily journal entries were recorded in my digital field research blog. Journal entries covered subjects such as student responses and highlights from the days’ experiences, archived in narrative format with images depicting the story.

**Data analysis**

The analysis of data from each case study team involved organizing then categorizing data into the themes. I organized the data chronologically, then selected data to analyze.

**Selection of data**

Since the data had been organized chronologically, I started to analyze the data from the beginning, so the brainstorming document was the first document coded. After coding the first few documents from each case, I began to see themes specific to each case arise. This lead me consider analysis of the end products next. I wanted to see if the same codes were present in each cases’ final project. I chunked each section, scene and some frame by frame sections of the final video for coding and describing. I started to make timelines, tables and graphs to reflect some of the data and themes from the code
events. I used primary documents like the brainstorming, poem, storyboard and video analysis to develop some of the initial ideas on how my data connected to the research questions. I then started to select more specific data that inferred the development of each cases ideas, for example the selection of data that showed innovative applications of technology, aesthetics or culture.

**Coding of artifacts**

I coded data using a spreadsheet. For the purposes of coding, longer texts were chunked into sentences or ideas. The codes I began with were 1) *science facts/concepts and scientific or technical processes*, 2) *social issues or concerns*, 3) *cultural contexts*, 4) *innovative application of technology*, 5) *aesthetic or expressive intent*.

Table 3.2 Primary Coding Scheme

<table>
<thead>
<tr>
<th>Theme</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEM facts/concepts included</td>
<td>A science, technology, engineering or mathematical concept, fact or process is present, suggested or expressed.</td>
</tr>
<tr>
<td>Social issues or concerns</td>
<td>A social issue or concern is present or expressed.</td>
</tr>
<tr>
<td>Cultural contexts</td>
<td>There is a cultural context present or expressed.</td>
</tr>
<tr>
<td>Innovative application of Technology</td>
<td>There is an innovative or new technique or process within the subject of media technology used, tried, suggested or explored.</td>
</tr>
<tr>
<td>Aesthetic or expressive intent</td>
<td>There is an aesthetic, expressive, artistic intent either applied or expressed</td>
</tr>
</tbody>
</table>

Coding of the final public service announcement video involved scene-by-scene and frame-by-frame analysis. Scene transitions and other changes were carefully coded using the same coding scheme. A description each piece of data the context of the data was recorded in a separate file. I quantified the number of times each piece of student work reflected each code as a way to compare the frequency of codes by case study team.
I also analyzed the aesthetic intent and qualities of each design team’s PSA. The purpose of aesthetic coding in this study was to analyze the ways the design teams made their aesthetic decisions and how those aesthetic choices may have been influenced by their personal associations and memories that exist within broader socio-historical contexts. Further, the participants’ individual and cultural frames of reference may have influenced their personal motivation to participate in the construction of their narratives or the technical development of their media projects.

Historically, theorists have valued aesthetic qualities such as realistic imitation, formal design, expressionism, symbolism, or functionality as important aesthetic qualities. These qualities inform this studies aesthetic analysis, I have chosen to code this project using approaches drawn from the contemporary literature found in Visual Culture Studies, which is derived from many contemporary scholars in art history, criticism, and art education as distilled by Pauly (2003). The aesthetic coding scheme was created using several of the major aesthetic values Pauly (2011) highlights in her research. The codes I used for the aesthetic analysis are 1) realist, 2) formalist, 3) expressionist, 4) symbolist, 5) functionalist, 6) contextualist, and 7) ethno-aesthetic.

<table>
<thead>
<tr>
<th>Code themes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realist</td>
<td>Represents or imitates nature</td>
</tr>
<tr>
<td>Formalist</td>
<td>design based on formal principles such as unity, balance, etc.</td>
</tr>
<tr>
<td>Expressionist</td>
<td>expresses thoughts, experiences or emotions</td>
</tr>
<tr>
<td>Symbolist</td>
<td>communicates symbolic or spiritual values</td>
</tr>
<tr>
<td>Functionalist</td>
<td>serves a particular function like a particular tool</td>
</tr>
<tr>
<td>Contextualist</td>
<td>communicate or critique personal or broad social, political, economic or</td>
</tr>
<tr>
<td></td>
<td>historical experiences, ideas, values or issues often with desire for change.</td>
</tr>
<tr>
<td>Ethno-aesthetic</td>
<td>continue or transform traditional art form passed down from ancestral culture.</td>
</tr>
</tbody>
</table>
Study Limitations

Several limiting factors played a role in the amount and quality of data recorded during this study. Several factors relating to IRB constraints and approvals contributed to the difficulty in fully researching this group of design students. For example, the IRB only covered half of the participating students in the study. Students from NAAC were omitted from the study because the IRB only covered students at SRU. This limiting factor also affected the quality of data recorded because less than half the students in the program were actually studied. Additionally, students selected in the study were all male students, which limits the generalizability of findings.

Another factor affecting the study was the fact that the students from NAAC were receiving grades and pay for their participation, while the students at SRU were not receiving grades but were paid. Because of this situation, it appeared that the SRU students were not as engaged with the learning materials and did not complete assigned tasks like reading and blogging since they weren’t receiving grades on those activities.

Future studies would need to include students from both collaborating institutions, expanding diversity and generalizability.
CHAPTER FOUR: RESULTS FROM CASE 1

Case 1: Team Rainwater Station

The team in case one created a PSA video that showed a stylized aesthetic intent. They focused on solving technical design problems for the immersive environment and expressing science content in their PSA video. My analysis highlights how students integrated science, technology, engineering and mathematics problem solving skills to address their content intentions, aesthetics and artistic design.

I first present an aesthetic analysis of their final PSA video, Rainwater Station. This analysis sought to understand how the students’ aesthetic intent informed their use of STEM and arts in the PSA. I then present my analysis of artifacts of their design process. This analysis aimed to trace the evolution of their science, technology, engineering and mathematic understanding related to the creation of the PSA.

Aesthetic analysis of final video

The video starts off with the sound of cicadas as the scene comes into focus (Figure 4.1). The title Rainwater Station moves forward and appears in the central bottom area called the sweet spot. The colors are brightly contrasted and pushed to extreme saturation, making the scene vibrant. There is a dry crack that appears across the screen just as the title comes forward, emphasizing the dryness of the environment.
The next scene presents the plot in a realist and natural representation of the desert (Figure 4.2). A sign swings in the dry wind, moving it back and forth. The sign reads *Next Rainwater Station 100 Miles*. The road ahead is dry and desolate; the image is real and seamless, giving you the feeling that you are in that desert. The camera moves forward and creates the feeling of moving down the road past the sign.
The scene fades to a view of people standing in line through the sweet spot across the foreground of the dome (Figure 4.3). This is the first perspective change. Aesthetically, the characters look like rugged westerners, in costumes that include cowboy hats, vests, and Native American attire. None of them engage the camera; they all seem to be looking onward or down to the ground. A Native American woman and girl stand at the end of the line, which was a conscious decision by the group, intended to challenge stereotypic historical-cultural narratives, and present a contextualized aesthetic.
The next scene shows the line of people standing in front of a shed with a water barrel in the foreground, you can now see the entire scene (Figure 4.4). The man standing in front of the shed is behind a wooden counter with a bucket. It is clear that this must be the station where water is distributed, and these people are in line for water. The design team implemented a set of culturally learned codes to express the aesthetic qualities of the people in line. For example, the people are holding buckets and they are dressed in a variety of western costumes. The props and costumes suggest that the viewer interpret the difficulty of finding fresh water in the arid environment.
In Figure 4.5, you can see the first character step forward to receive water from the Rainwater Station, approaching the water bearer at the counter. The line seems to progress as a new gap in the line of people is shown as he steps forward. This portrays the feeling that the line is moving forward, and people are interacting with the Rainwater Station.
Then, a dramatic shift of view puts the audience into the line of people by shifting the perspective to an over-the-shoulder shot of the fifth person, excluding the Native American woman and girl (Figure 4.6); this provides the perspective of standing in line, looking directly toward the water bearer. You see the next person, holding a small bucket, step forward for water and the water bearer gives him water. It places the line of people in juxtaposition to the water bearer who is a white man with a white beard. This scene progresses when the person getting the water walks to the right and the scene fades into the next person stepping forward to get water from the same perspective.
Figure 4.6 Over the shoulder line shot (00:30).

Figure 4.7 shows the man walking off to the right of the shot after receiving water. The shot fades into the next scene where the next person in line steps up for water. These fades go almost black before transitioning between the scenes.

Figure 4.7 Actor walks off stage to right side of dome (00:51).
The next scene shows a white woman in line receiving water (Figure 4.8). You can see her reach the bucket forward and you hear the sounds of the water pouring. The sky is dark and the time-lapsed clouds move above the viewers' heads at the top of the dome, helping the audience feel like they are literally in a real environment. The line has progressed and viewers have watched three people receive water from this angle, with gentle fades as the actors walk off to the right after getting their buckets filled.

Figure 4.8 Woman steps forward to get water from the Rainwater Station (01:02).

In the next scene, the perspective shifts, showing the line of people from the side; the next man in line approaches the Rainwater Station (Figure 4.9). This scene shows the actors at a midlevel shot, keeping the audience engaged in the action of the line of people waiting for water.
In the next scene, the water bearer realizes there is no more water in the bucket by looking into the bucket (Figure 4.10). The perspective changes from the sweet spot to the top of the dome—the zenith. The viewer appears to be inside the water bucket looking up, seeing a man with a large ladle trying to scoop water over the edge of the empty bucket. You hear the voice of the man behind the counter say, “we ain’t got no more water.”

The water bearer is now seen close up with glasses, white beard, and cowboy hat expressing the white mans' western aesthetic, which is a dominant cultural narrative in western society. The audience may interpret this content based on their culturally learned codes of representation, which have been contextualized.
The next scene progresses the story further, as the scene changes back to a profile view of the line of people, and we watch the actor who asked for water walk away from the Rainwater Station (Figure 4.11). He walks away with his head down, dejected because there is no more water. He expresses his disappointment in not being able to receive any water with his body, slouching and head down.
In a continuation of the scene (Figure 4.12), you don't see his face; he is an anonymous character who could be anyone and everyone, helping the audience to place themselves into the narrative. The scene is realist because of the characters’ natural interaction with the environment. The rest of the characters in line start to exit the stage toward the camera following the first actor off the screen.
The little girl does not exit the scene and instead follows the hose to the water barrel, to the foreground of the shed (Figure 4.13). The little girl is breaking societal norms by being inquisitive, which suggests an ethno-aesthetic approach to this contextualized scene.
She finds the water barrel, filled with rainwater on one side of the shed while the water bearer is off on the other side of the shed (Figure 4.1). She looks inside the water barrel. This grand moment is where she finds the solution to the water problem. The director seems to have intentionally placed this little Native American girl in the role of problem solver. The team intended to challenge and to respond to traditional passive roles, societal and cultural narratives that have been associated with Native Americans and women in ethnocentric traditional media. This is a contextualized design decision that expresses the teams’ ethno-aesthetic.

![Figure 4.14 Little girl looks inside the water barrel (02:00)](image)

The final shot of the scene shows the little girl as she looks into the water barrel (Figure 4.15). In this scene, the little girl is seen from inside the water barrel as she looks down. The perspective shifts as it did earlier to the zenith, as the audience now sees the little girl look into the barrel, from inside the barrel. She screams “Mom!” as she looks inside. Above her, the sky has become stormy, creating a real and natural setting. Rain begins to fall into the water barrel as if the sky has broken and now the rain barrel is collecting water. The scene fades to black.
This scene shows a young girl empowered as the problem solver. The team intended this aesthetic design to challenge cultural narratives about power and intelligence, with specific regards to gender and cultural identities.

After the girl yells for her mother, the scene fades to black and the narrative ends. The next scene fades into the sweet spot and delivers the call to action for the PSA (Figure 4.16). The scene shows a black background with white text in an old west font in the sweet spot: “Catch The Rain: Simple, Sustainable, Economical.” Cicadas buzz loudly. The text wraps around the dome and delivers the call to action for the audience, suggesting that catching the rain is simple, sustainable and economical.
In Figure 4.17, the scene continues and fades into the next frame with more text providing some statistics on rainwater collection. The background is still black, and the cicadas are still buzzing. White text reads in the same western style font, “Average US Annual Rainfall (8–30 inches per yr) catch 7,500–28,000 gal/yr.”
The overall aesthetics of the Rainwater Station PSA delivered a realist and naturalistic form of cinema in their PSA. They used formal design concepts and principles to guide the design of their PSA. The students stylized it in the form of a Hollywood film where the audience can become a part of the action, engaged in the cinematic event. The narrative challenges stereotypes about Native Americans' and girls' passivity and lack of agency. Instead it depicts a Native American girl as instrumental in solving problems by breaking the rules.

Each frame was coded using aesthetic analysis (Figure 4.18), finding that the design teams’ focus was to deliver a contextualized ethno-aesthetic, engaging realism and formalism to support their approach. This realist, formalist and contextualist focus was visible even in their initial brainstorming document (Appendix E).

![Rainwater Station aesthetic analysis of final PSA](image)

Figure 4.18 Rainwater Station aesthetic analysis of final PSA.

The aesthetic analysis of the brainstorming document revealed a focus on contextualizing their PSA aesthetically as an advocate for social change (Figure 4.19). They focused on the use of social issues to deliver the message of water conservation. Their narrative eventually developed a popular context of breaking traditional social norms, like Native Americans at the end of the line or girls following in line a clear use
of ethno-aesthetics. The aesthetic analysis of the group’s brainstorming document and final PSA show the group’s intention to contextualize rainwater collection socially. Using a western style to express realistic and formalistic design qualities helps to contextualize traditional dominant western stories.

Next, I present analysis of artifacts of the teams’ design process, from their first brainstorming session, tracing the evolution of their ideas. I examine their learning, exploration, and use of science, technology, engineering, and mathematics concepts and practices. I then explore the degree to which each of these were integrated with the arts in their PSA.

**Thematic Analysis 1: Science and society in the development of Rainwater Station**

The students in this team located over 60 ideas in their initial brainstorming document. Based on my analysis, there is a clear emphasis on social issues and science content as potential ideas for their PSA (Figure 4.20).
Figure 4.20 Number of ideas coded as STEM facts or concepts, social issues and concerns, cultural contexts, Innovative use of technology, and aesthetic intent on the brainstorming activity.

Their recorded ideas in the brainstorming document built on each other. For example, team members asked, “Where does water go after we use it at home?” They answered, with a possible idea, “The cycle of water from home [to the] Rio Grande [River to] Texas [and finally to the] ocean.” Another participant suggested that they show that “Water goes down the drain and then we follow it to where it goes.” These ideas seem to build upon each other, as they ask one question, it leads to another.

After brainstorming, the students created the next document (Appendix F) as they sat together in the lab and searched on multiple computers. They wrote lists of websites citing a few statistics about Albuquerque’s annual rainfall and water harvesting. For example, the students recorded annual rainfall for Albuquerque as, “Over the past 30 yrs, the avg annual Abq rainfall is 9 inches.” Even the name of the document, WaterHarvestPSA.rtf, indicates that the group has made some kind of decision about their PSA’s narrative focus. They also listed a website, “waterharvesting.com,” and
statement, “Great Interview” about water harvesting website. I tried to follow the links and found the website URL they included was wrong or was no longer live, but I did find a website, “harvestingrainwater.com,” which is maintained by the same person they listed, Brad Lancaster.

The students archived additional websites and topics of interest for their PSA narratives (Appendix G). This document shows that they considered many different social and even cultural implications when constructing the initial ideas for their PSA. For example, they listed groups such as Occupy New Mexico and National Tribal Environmental Council as possible resources for topics for their PSA. This research is evidence suggesting their cultural intentions for their PSA. The students were engaged and looking for a social problem to frame the science content in their PSA narrative. The students decided on the rain barrel as an expression of water harvesting, but they looked for a social aspect to frame their narrative around.

Thus, analysis of the brainstorming document (Appendix E, Figure 4.20) and initial research shows the students’ initial interest in science concepts concerning water conservation. Although they researched science concepts on the topic of water conservation, this is seen only in the final seconds of the video, when the students include statistics about rainwater collection at the end of their PSA (Figure 4.17).

**Thematic Analysis 2: Aesthetic intent pushed the students to use technology, engineering and mathematics to solve challenges**

In post interviews with Connor and Mark, they revealed that one of the driving aesthetic intents for their PSA was to create a Hollywood-style movie grounded in realism. In the transcript below, Mark reflects on how their PSA differed from the other teams’ PSA and how he remembers starting the project.

Mark: I think we, we went about it in a different way than the other team even from the start because we were trying to use some technical things that we didn't know if we could do or not within the dome. So we were trying to figure out some of these technical issues even before the story was even, you know, kind of created. So, you
know, there's not very much video shown in the dome, so we kind of had to figure out how we were going to go about that even without the story being written. Cuz, we knew we kind of wanted to go in that direction from the beginning.

Jane: So you set yourself up almost some technical challenges or problems that you wanted to accomplish?

Mark: Right, we, we wanted to utilize video as opposed to just doing every thing kind of in the atmosphere of After Effects. Which is what a lot of these dome pieces come from, you know just straight from After Effects, no real life, you know, situations or videography.

Their initial aesthetic choice was based on a style of videography, according to the student, to present a real life feeling. This aesthetic decision to produce a fulldome PSA using traditional cinematic styles created several challenges. First, they had to find a way to deal with cuts and transitions; they solved this problem by (a) changing perspective and (b) using dome perspective. Second, they wanted to create realistic animated scenes from still photos, a problem they solved by learning to zoom in while remaining within the dome master. Third, they used green screen shoots to solve challenges related to distortion of live action. Fourth, they had to figure out how to have the actors exit scenes without distortion, a problem they solved by having actors walk toward the camera. Fifth, they used engineering to place lights and cameras during green screen shoots.

The analysis below demonstrates that the students solved complex problems using technology, engineering and mathematics, with the intent to create the aesthetic they desired.
Cuts and transitions between shots by changing the perspective

One of the challenges the students navigated was how to make cuts and transitions between scenes. Figure 4.21, is an example of one of the transitions between shots. In his interview, Mark explains why this was a challenge:

Mark: Cuts are a little bit different in a fulldome so we were having to figure out some of those issues as well you know standard cuts that you would see like on that they do every three seconds in a damn movie, you just can't do that in the fulldome cuz, first off it will probably make you really dizzy, secondly it’s just such a large medium that you have to figure out other ways to transition in between shots a lot of times.

The sequence of scenes shows an image sequence revealing an intentional aesthetic choice by the students to create a cinematic transition between scenes by fading to black between transitions (Figure 4.21). In an interview, Mark explained:

Mark: The cuts we did have some hard cuts but for the most part, most of our transitions were fade-to-blacks, kind of, so that the audience kind of had a sense of that shot was over, cuz if you just do a straight cut it almost gets disorienting.

Figure 4.21 Sequence of scenes showing fade to black between scenes

In Figure 4.22, the transition between the scenes shows the actor from the first scene walking off the stage toward the camera; the perspective changes to an over-the-shoulder shot of the line of people. This puts the viewer into the line, creating a cinematic aesthetic design choice to accentuate the realism in their PSA.
Connor also discussed the deliberate choice to create a cinematic feel:

Connor: I think that our is interesting because it tried to really immerse you in an environment […] Ours is trying to stay within, in this very cinematic realm of always just having the shot go from one shot to the next and have like this relationship from one to another.

The deliberate decision by the group to create this type of cinematic experience in the dome challenged them technically, engaging them in problem solving activities that expressed a strong interest and opportunity for this group in arts and technology learning.

**Using dome perspective to cut between scenes**

The students also used dome perspective to cut between scenes. (Figure 4.23) They used a GoPro camera inside the bucket, holding a green screen tautly over the actor’s head to create this effect. The edges of the camera frame didn’t totally capture the edge of the bucket, and the students didn’t fix this scene. Image (a) shows a man approaching the water bearer. Image (b) shows the water bearer looking into the bucket, looking for water. He turns the ladle upside down to show that there is no water. You then see the ladle overhead at zenith, with the water bearer looking down onto the audience, with bright blue sky and clouds overhead.
Connor discussed this aesthetic choice in his interview, highlighting the deliberate use of the dome and the GoPro camera:

Connor: Towards the end when it’s looking up out of the barrel, but it was definitely trying to utilize the dome for what it has to offer and kind of activate the space a little bit more. So I think that the one barrel shot or the water shot that we used the GoPro kind of added a little bit more motion to the piece. [...] I think the GoPro was pretty good for the dome because it has a wide angle view, so it could have been a lot worse if it were like a smaller camera that only occupied like a quarter of the dome.

He also explained how the idea evolved, that “it wasn't so much based from the beginning.” He continued,

Connor: We had done quite a bit of testing with the GoPro prior to even writing the shot list and the script, so I think it was always kind of in there that those would be shots, I think it was the water barrel like looking into it, was the first one we came up with, and then it kind of made sense to have the saucer pan kind of the same way. And so I think we planned on that I guess it was just kind of, it felt more after the fact, like in the sense that while we were filming it it felt rushed.

Mark discussed how his design team chose to use the GoPro camera, and why that worked.
Mark: We played with what type of camera we would use back and forth because we didn't know for certain, right away. […] We knew that the GoPro wouldn't cover the whole dome and that was part of the problem with, we thought we were going to have face, you know if we use one of these larger cameras like the 5D we could actually get a whole shot, but the thing is, is these spaces we were going to put the camera were tiny so, we were trying to figure out how we’re, we’re going to get these shots made, because basically, it was a video you know and the GoPro actually did a really good job of making that video for us inside of that rain barrel. And we didn't know how it was going to turn out, it was one of those things we were experimenting.

The students' deliberately chose to use certain technologies to try and create certain aesthetics, expressing their cinematic intentions for the PSA.

**Zooming inside a dome master to animate a photograph**

Figure 4.24 shows screen shots from the fulldome-ae-test.mov produced during the first week of the internship by the Team Rainwater Station. This video was created after the fulldome 101 introduction to spherical photography and 3D construction of a Maya sphere for the fulldome. The students used a spherical panorama they shot to test how to rotate the shot with the dome master. Figure 4.26 (a) Shows the start of the video sequence with the dome master mask present. (b) – (d) Show the dome master mask grows, as the video rotates. (e) Dome master mask is lost. (f) Dome master mask template for reference.
In the final PSA, the students created the feeling of the audience moving down the road (Figure 4.25). The scene from (a) to (b) is a dissolved transition, with slow zooming action from the camera. In image (b), the sign sways back and forth as the camera appears to move past the sign, making you feel like your walking down the road. This required the students to create feeling of moving forward, so it appears to the audience that they pass the sign. In contrast to their first test (Figure 4.24), the final PSA, shows that the camera zooms in and the mask is still present as the movie continues (Figure 4.25), showing that the students figured out how to keep the mask in place while zooming and moving the virtual camera that records the zoom motion.
Figure 4.25 Team Rainwater Station solves mask and zoom technical issues

**Green screen spacing and stitching to avoid live action distortion**

In figure 4.26, you can see the line of people across the bottom of the screen; this was created through a complicated process of green screen stitching. There are gaps between groups of characters to support postproduction stitching. In this image, you can see two such gaps: between the first and second, fourth and fifth, and the seventh and eighth people in line. The students stitched these three different green screen shots together to make one big scene across the bottom of the dome through the sweet spot.
Their solution for this problem can be traced by examining their shot list, a document drafted the week of the shoot. The shot list was created by the director and distributed to the design team. It contains instructions for carrying out the green screen shoot at SRU. For shot 3 and shot 5, the director included a “gap of 3–4 feet between characters” so that the shot could be stitched in postproduction.

Figure 4.27 shows a series of photos shot during the green screen shoot. The photos document some of the process and technical details the students coordinated to accomplish their green screen goals for this project. The photo sequence shows spacing of actors during the green screen shoot. Image (a) shows the water bearer. The man holding the bucket is separated from the man and girl behind him in line by several feet. In image (b) you can see the man and girl at the end of the line. The students shot the actors in position to stitch this view across the dome. Notice the gap in image (c) as the line of actors continues.

These gaps helped them stitch the green screen shots together using After Effects software during post production. After stitching together, the scene looks as if it was shot as one complete scene (Figure 4.28). The students devised this process for stitching together large format green screens using standard video resolutions. They used the green screen technology to get the video to map around the sweet spot of the dome. This technique accomplished not only some important technological innovations for shooting multi-green screen shoots, but it also helped the students express their aesthetic intention of having the production feel like a movie. In image (a) we see the line of people stitched together from green screen shots. They cut up the green screen shots as the line moved forward. The actor who has approached was shot individually with the water bearer actor.
In image (b) we see the extra space that was created between the first two actors in line. The man and the girl were shot second and the other man, and the Native American woman and girl at the end were shot third. In image (c) we see the actor who received water turn toward the camera and appear to step forward.

Figure 4.28 Scene after green screen spacing and stitching

Analysis revealed how the students planned their multiple green screen shots. I compared the student shot list and their sketches to photos taken during the green screen shoot (Figure 4.27), and screen shots from the final video (Figure 4.28). These articulate how the students engineered a dynamic green screen shoot, capturing the sequence of scenes from multiple cameras and stitching them across the large dome surface. The students had to create a way to stitch the green screen video together in After Effects so the shots would appear natural in the environment of the dome. They accomplished this cinematic aesthetic by devising a way to shoot video that could be stitched together in the final dome master.

**Exiting toward the camera without distortion**

The students faced a challenge about how to have the actors exit the screen or frame naturally and without distortion. They decided it was too difficult to have actors move off the screen to the right or left, because the screen doesn't end like a typical flat screen. They decided to have the actors walk off toward the audience, at the sweet spot (Figure 4.29). The actors did not walk completely off the edge of the dome, instead they faded to black before the next shot. Having the actor walk off the screen toward the audience was a new way to implement a video transition in the dome. It supported their attempt to have live actors leaving the scene, something the students innovated as a cinematic aesthetic.
Using engineering to place lights and cameras for a multi-green screen shot

Team Rainwater Station participated in complex problem solving skills that engaged engineering in the immersive environment. The students had to engineer the lighting for the green screen, marking, measuring and placing the lights to best capture the actors using multiple shots. The team planned and executed the multi-staged shoot in the green screen studio, an innovative approach for engineering a large format green screen shot.

The students used green tape on June 18, the day before the green screen shoot, to mark the camera positions and some approximate positions of the actors and props. In Figure 4.30, the image (a) shows the students setting up the lights for the green screen shoot. You can see the floor is clear of green tape, however in image (b) and (c) you can see the students have applied tape on the floor to guide the lights and cameras into position. In image (c) you can see the tripod leg has green tape on the floor, showing the exact position for the tripod during the shoot.
Students referred to the shot list and the Lighting Set-up Document, which is located in the Director Notes document. In the section labeled Lighting Set-up, the director indicated that the light positions are marked with gaffing tape, just as seen in figure 4.30.

NOTE: All lights will stay in the same place for shots 1–7. Shot 10 is where we move light #99 to “light 10” on gaffing tape.

The director also provides exact directions for each light and general guides for the lights and the studio house lights.

1. All lights have diffusers
2. No “house” lights
3. Light numbering below goes by the last 2 or 3 digits of the barcode number (sticker on light or stand)

The Lighting Set-up guide also provides directions for each light. For example,

#99

Standard height (no extension)

Light switch 1 on, all others off
Floor light (not on stand)

All light switches on

The director’s notes detail how much of the light is on, as several of the lights have two or three phases for a varying brightness.

Additionally, in the shot list document, the director has made notes on where to place actors and props. The students had to mark certain positions, such as the position of the barrel in reference to the actors or the computer-generated shed. Using the shot list and the director’s notes, the design team engineered a complex method to organize the actors on the stage, so they wouldn't create shadows on the green screen, which required sophisticated light engineering.

The students developed a detailed engineering plan for actors, props, lights and cameras during the green screen shoot, which supported their aesthetic goal to produce a cinematic style movie for their PSA.

**Using mathematics to solve technology problems**

From the first day of the internship, the students were introduced to mathematical concepts about the fulldome environment. They had to develop a basic understanding of the geometry of domes and spheres.

During the first week of the internship, students completed surveys that to provide a baseline of their knowledge about immersive environments. They were asked to explain and describe the immersive environment using words and a hand drawn image. Their responses indicate an understanding of the immersive quality of the environment, but only a superficial understanding of the relevance of the mathematics.

The immersive environment puts the audience in the center of the frame. And makes them feel more immersed. Creating an environment infers even the peripheral vision is involved, allows for a suspension of
disbelief. The immersion engages the audience a ways cinema can not, and more than with VR.

An immersive environment is an environment that surrounds the user or viewer with visualization and sound. It is called an immersive environment because it immerses the audience with content 360 degree of view.

After students developed a basic understanding of the immersive and geometric environment of the fulldome, they were taught about spherical photography and how to use the Nodal Ninja. They had to learn how to use the nodal ninja, a tripod head that allows the photographer to adjust the camera to specific angles to support the precisely mathematical application of shooting spherical photography. To support them, they used a worksheet to calculate the number of images required for a specific degree of rotation or degree of altitude adjustment (Appendix C). This is an important procedure to learn so they can accomplish shooting spherical photography in the field, where they may not have access to an online calculator

In an interview with Connor, he describes using mathematical concepts, such as parallax when shooting spherical photography. However, we also see that the student discovered a way to circumvent calculations; an instructor showed the student how to use technology to set the nodal ninja instead of calculating it.

Connor: I think you know just learning that we're dealing with a 360-degree space and how to break that up for the field of view of the camera and how many degrees you had to move up and down, like vertically and horizontally, was very, engaged my math skills a lot, but I kind of ended up just using an application that [an instructor] showed me that like kept me from, or kind of helped me avoid having to do the math. [...] I guess that's kind of using like technology in a way to help you solve your problems. We're kind of like overemphasizing on that a lot and I could, you know, I guess kind of figure out using the, I think it was the parallax, to try
to figure out like you know how much the camera moves every
time and then just kind of being able to figure out how many
degrees that would end up being.

This transcript highlights that Connor engaged his math skills for the fulldome and expanded his understanding of the geometry of spheres. However, because an instructor showed him how to use a spherical photography calculator online, he missed an opportunity to really learn how to calculate this on his own. Because Connor missed this critical learning opportunity to calculate the adjustment of the nodal ninja, he will not be able to use the nodal ninja when he doesn't have access to the online calculator.

**Discussion of STEAM integration**

The students made an aesthetic decision to produce the PSA in the format of a movie using realist and formal qualities found in traditional cinema. This forced them to explore and innovate new ways to accomplish traditional cinematic techniques such as cuts, transitions, actors exiting off stage, and capturing large format green screen shots.

The analysis above shows the students integrated technology and engineering with arts; the problems they solved required them to learn new technology skills. They used technology in innovative ways. The students engaged in engineering by learning how to place cameras and lighting to capture technically difficult shots for the immersive environment.

Designing for the immersive environment also created opportunities for students to learn complex math concepts; these included zenith, parallax, longitude and latitude. Understanding geometric concepts were required for them to produce content for the fulldome environment. However, students were able to use technology solutions to avoid certain calculations, suggesting that while they integrated conceptual understanding of the mathematic concepts, they did not need to gain or apply an algorithmic understanding. This finding highlights how well the technology and engineering were integrated with the arts.
While the students did engage in science learning about rainwater collection, during their initial research phase, the science was not well integrated with the arts; in fact, it was a literal postscript to their video. They integrated the science content with a social framing in their PSA. Although the students spent time researching science concepts related to water conservation, only one of those facts were included in their PSA as a part of the call to action for the viewer. The analysis suggests that the students participated in surface-level research activities around the subject of water conservation indicating some engagement in science learning. However the science learning was not well integrated into the structure of the class, despite the framing in the project launch document for including science concepts and facts into the PSA.
CHAPTER FIVE: RESULTS FOR CASE 2

Case 2: Team We are Water

The team in Case 2, We are Water, created a PSA video that expressed cultural content using symbolic and ethno-cultural aesthetics. My analysis highlights that the team focused—from the launch of the project—on artistic expression and aesthetics to express ideas about water conservation, instead of conveying STEM concepts and facts around water conservation. I present my analysis of how the team expressed cultural aesthetics and contextualized science in social issues using metaphor to advocate for social change around water conservation, but failed to deliver any specific water conservation messages. The students may not have understood the importance of incorporating science facts and concepts into their PSA; their focus instead was on artistic development.

I present my analysis below. I focus first on aesthetic analysis of their final PSA. I present my analysis of their initial brainstorming ideas, showing how they used art to develop a contextual message of conservation. I then present analysis of a poem showing their development of a contextual water conservation message using metaphor. I show how they further developed this into a narrative, using a game I engaged them in. I finally present analysis of how they struggled as a team, and how this resulted in their decision to use familiar technical skills rather than innovating and solving technology problems.

Aesthetic analysis of final video

In the opening scene, the dome is black with sounds of water dripping, echoing in a hollow space (Figure 5.1). The students express an aesthetic intent by initiating the sound before any visuals appear.
Figure 5.1. Opening scene (00:00)

The scene slowly comes to life as the sun appears over the horizon and red, green and blue silhouettes emerge from the foreground, dancing (Figure 5.2). The scene is natural and realist, except for the silhouettes, which are symbolic. The dancers start to move; it is an awkward moment because you see the silhouettes dancing, but you only hear the water dripping. There is no visual water reference.
In the next scene, the beating of the drum and chanting start as the silhouettes continue to dance (Figure 5.3). The sound of drums and chanting create a cultural intention for the piece, implying a rhythm inspired by Native American drumming. The sun continues to rise and you begin to see more of the landscape around you. The placement of the silhouettes and the darkness of the shadows in the foreground was an interesting aesthetic decision. A poem is read over the sounds of a beating drum and Native American chanting starting at 00:09 seconds, "Creator of the Universe."
The foreground starts to come into perspective, and features start to become noticeable around the silhouettes as the sun rises (Figure 5.4). The silhouettes—each a different color—seem to symbolize some kind of individuality. Each of the silhouettes has an individual style of dancing that is unique, possibly symbolic of differences in the dancers, perhaps symbolizing diversity. The foreground comes into view as the sun rises, and the landscape comes into view. The poem narration continues, "Creator of Mother Earth, we thank thee for giving life."
The scene fades into a brighter daytime scene near a lake. The sun has risen and there is a rocky beach in the foreground where the silhouettes dance (Figure 5.5). The silhouettes seem to merge into one red silhouette and transform into a shadow of a dancer cast on the ground. The photographic imagery of the scene presents a realist aesthetic intent. The poem narration continues, "to our heart beating in sync with the rhythm of the drum. Thank you for giving us good health."
When the chanting starts, the ethno-aesthetics of the piece are brought to attention. More dancers’ shadows emerge from the central shadow. At first they are all red, then change to blue and then green as the final dancer’s shadow emerges (Figure 5.6). They appear distorted and strange, not as clear as the previous silhouettes. The poem narration continues, "Allowing us to hear the song of the earth."
The green shadows become gray, and black-and-white video dancers emerge from their shadows; they are human forms dancing in harmony together on the beach, in front of the realist lake scene. Each of the dancers holds a basket, which appears to be Native American with patterns and symbols, suggesting Native cultural aesthetics. The dancers move in unison together. Their black and white presence is translucent, making them ghostly with the highly saturated imagery of the landscape background that moves slowly behind them. The poem narration continues, "On this day we give thanks, for eyes to view your creation and its beauty. Thank you for teaching us."
The dancing continues as the scene begins to rotate to the right, shifting the dancers off to the right side of the stage. As the scene rotates, their shadows begin to transform back into colored shadows that match each dancer (Figure 5.8). The translucence of the dancers shows some of the background image through their bodies. The shadows are nicely captured and laid over the background image showing the texture of the earth below. The horizon shows through the dancers, giving them a feeling of not quite being there, almost spirit-like, a possible ethno-aesthetic intent. The poem narration continues, "about the universe and life."
The dance ends as the next scene comes into view in from the left (Figure 5.9), shifting the scene to the right and then introducing the next scene on the left. The ghostly figures with their red, green, or blue shadows fade. A translucent red square moves into the scene from the left.

The red square moves into the sweet spot of the dome and we see that it is a video screen, tinted red. The video shows a man using water, possibly wasting the water. We see what looks like an animation of water coming from the back of the dome, over zenith, down toward the video screen. The perspective of the shot puts the audience below the actor looking up from the sink and drain.

The red silhouette appears below the video screen, and appears to catch some of the water that is being wasted in this symbolic scene. The basket the silhouette holds seems to be used to collect the water from this animation, a possible metaphor using symbolic and expressionist aesthetics. The poem narration continues, "We are reminded of our ancestors who honored the water and the land, we give thanks.”
The scene transitions when a blue tinted video screen and silhouette appear to the right of the red video screen and silhouette (Figure 5.10). The blue video screen shows water being used to water grass and landscaping, and the blue silhouette appears to be catching the water below the video in an effort to symbolically conserve or protect the water from being wasted. The red video is still showing the man, now clearly brushing his teeth in the sink. Both of the silhouettes appear to try to catch the animated water in their baskets. The poem narration continues, "for those sacred beings which continue to guide us everyday. Thank you creator for the clouds and father sky, thank you for the rain."
In the next scene, a green video screen and green silhouette appear to the left (Figure 5.11). The green video screen shows a canal or irrigation ditch for farming. The green silhouette catches extra water from that video too. The red video screen displays two people in a kitchen doing a variety of cooking tasks that include water usage and potential for wasting water. The blue video shows water running off from the previous scene where the water was being used for irrigation. The metaphor that expresses and symbolizes water conservation is becoming clearer. The poem narration continues, "that replenishes mother earth and her thirsty cries, with good hearts we pray."
The scene fades into a close-up view of a sink drain at the zenith with water running into the drain (Figure 5.12). The edges of the drain fade to black and the video slowly zooms into the drain as the water is shown running out. The silhouettes in red, green and blue stand with their baskets around the drain as the blackness closes in on the drain. They seem to be crouching and then standing up. Poem narration continues, "We pray that the rain will fall filling the oceans."
The blackness around the drain slowly overcomes the drain (Figure 5.13). The silhouettes hold their baskets as if in offering or receiving from the drain in this symbolic scene as the drain is presented in a realist form, but is symbolic of wasting water. The poem narration continues, "rivers, lakes and streams with hopes and dreams."
It is not clear until the next scene that the water is being sent from the dancers to the drain (Figure 5.14). The drain is nearly completely engulfed by the black circle. Animated water sprays from the silhouettes toward the drain, which then transforms into an animated rotating Earth. The poem continues, "We pray the people using this water."
In the next scene, the silhouettes appear to be spraying the Earth with water from their baskets (Figure 5.15). The Earth spins very slowly as it grows in size. The chanting and drumbeats continue as the poem ends. With the Earth now central, the silhouettes, in their diverse colors, seem to represent the diversity of the people on the planet. The poem continues, "will save and protect it."
The figures disappear and only the image of Earth remains huge over head, centered in the zenith of the dome, rotating (Figure 5.16). The Earth slowly fades away into the distance at zenith. The image—a satellite photo—presents a realist context and represents our connection to earth. The poem narration continues, "embodying the water as their way of living, respectfully using water, giving life to the land."
The final scene (Figure 5.17) presents a stylized graphic of the silhouettes inside a giant water drop. Smaller water drops slowly drip over the title of the PSA "We are Water..." The silhouettes have hands raised up toward the water drops and the title. The silhouettes have defined shadows as well as simple dark radial shadows. This helps the silhouettes emerge from the ground space as real but also spirit like figures that could represent any diverse community. The poem narration continues, "which sustains us, honor the earth, respect water and preserve life."
The overall aesthetic of the PSA was symbolist, realist, and expressed an ethno-aesthetic intent (Figure 5.18). The team made a variety of aesthetic choices. Much of their design was based around basic principles of design like unity and balance; therefore, many of their scenes express these formalist qualities. They also used the body language of the dancers to express water conservation by having the dancers give and receive water with their baskets. The baskets, drums, chanting and poem all situate the issue of water conservation from a Native American cultural perspective. The diverse colors of the silhouettes suggest an ethno-aesthetic twist, contextualizing the issue as relevant to diverse groups of people, with the realist Earth further signaling this as a global concern. The poem seems to present a Native American view of water conservation and respect for natural resources.
Thematic analysis of the final PSA highlights that the team presented water conservation aesthetically; while the main idea may have been based in science, the final piece did not deliver any clear science concepts or facts about water conservation, as had been instructed. (Figure 5.19) illustrates the absence of STEM facts or concepts in their final PSA. The students applied technology they learned in the internship in familiar ways when creating their PSA. Thus, although technology was integrated well with the arts to accomplish their project, technology *learning* was not well integrated. The students engaged aesthetic or expressive intent to deliver cultural and social concerns about water conservation.
Art for expressing science as a social issue

From the beginning, Team We are Water focused on a stylized artistic narrative that contextualized water conservation; they expressed this using a variety of aesthetic viewpoints, such as realism, formalism, symbolism and expressionism. I coded each idea on the team’s initial brainstorming document into a specific category (Figure 5.20). A majority of their ideas were categorized as social issues or aesthetic/expressive intent. The brainstorming document is the first indicator of the direction of their project, away from STEM and focused on social issues and aesthetics.
Some of their other ideas touched on science but also reflected a social issue; these were coded both as science facts or concepts and as social issues. For example:

How we conserve water, how much water we conserve in daily life, how much water we use as individuals and communities, corporations and they drain out lakes and rivers in communities and how that can be a problem for communities.

This idea engages science content, but situates that content socially with the final statement, “problem for communities.” To better understand how they used aesthetic intent to deliver science content, I further coded their ideas on the brainstorming document using the aesthetic coding scheme (Figure 5.21). They used realism and symbolism as a way to contextualize the science concepts. There are also instances of ethno-aesthetic ideas, including specific Native American traditions surrounding water, grounding their plans for their PSA in context of metaphor.
Figure 5.21. Aesthetic analysis of brainstorming document

Many of their initial ideas focused on realism as a way to represent real environmental situations. This realist aesthetic intent, paired with shallow understanding of relevant science content is visible in Stewart’s reflection on their PSA:

Stewart: We were just trying to show that Earth could, like, potentially run out of water and trying to get good juxtaposition of not only the landscape, but also how water interplays into the landscape and then showing that drain at the end, like, it’s all going away. Like, if we don't do something, if we don't get proactive, we could lose all the water on our lovely planet. You know, it’s not going to be blue any more. It’s going to be brown.

Stewart reveals that the group’s focus was to use realist images of landscapes, drains and other imagery to help the viewer interpret the aesthetic narrative about water conservation. His comments also reveal a shallow understanding of water conservation; while water conservation may be a global concern, there is no danger of the Earth losing all water and turning brown.

Analysis of We are Water's pre-production documents shows a lack of research on science concepts and facts. Stewart claims it was because the group never turned in
any documentation of their research; however, I believe their focus was instead on aesthetic development.

Stewart: We did do research on water sustainability. In fact we had a meeting with the water department of Albuquerque, some—it might have been the pollution. I don't know. The pollution control? But that ended up falling through or we didn't have enough time. I forget what it was. So, but, we had done research into water conservation before the project. And, like, the sustainability and the problems, some of the big major problems that are going on with water.

From the interview with SRU student, Stewart, I infer that the group researched science content superficially; they included a few broad concepts in their research, such as ‘water is life,’ and human bodies are a certain percentage of water. Despite this, Stewart asserted that he learned:

Stewart: I learned a good amount of information—stuff that I didn't know before. I mean, I just, there’s so much information going around in my head right now. You know, I just try to hold it all in there, but, yeah, not—it definitely helped me and I've become more water conscious since then.

Stewart connected to the concept of water conservation, but given the scant evidence—from the PSA, the team’s design work, and his own reflections, it is unclear if he gained the knowledge to follow through on being “more water conscious.” The hesitant, choppy style of his speech and lack of specific examples of things he learned further suggests that while they may have reviewed science facts and concepts, Stewart, at least, did not retain them. Although the team did not communicate scientific facts and concepts, they did communicate a socio-scientific concern. Given Stewart’s reflection, this concern seems real, but not well connected to action.

**Students contextualized their PSA through a poem**

Team We are Water developed the poem used in their PSA. The poem presented a primarily symbolist and ethno-aesthetic intent, but still connected this to ideas of water
and water conservation using metaphor. For example, they symbolized their connection to water using realist and contextualist elements. And ended the poem with a direct call to action.

Creator of the universe,
creator of mother earth,
we thank the for giving life to our heart
beating in sync with the rhythm of the drum.
Thank you for giving us good health,
allowing us to hear the song of the earth.
On this day, we give thanks for eyes
to view your creation and its beauty.
Thank you for teaching us about the universe and life.
We are reminded of our ancestors
who honored the water and the land.
We give thanks for those sacred beings
which continue to guide us everyday.
Thank you creator for the clouds and father sky.
Thank you for the rain that replenishes
mother earth and her thirsty cries.
With good hearts we pray the rain will fall
filling the oceans, rivers, lakes and streams,
with hopes and dreams.
We pray the people using this water,
will save and protect it.
embodying the water as their way of living.
Respectfully using water,
giving life to the land which sustains us.
Honor the earth,
respect water, and preserve life.
The students used the poem as a way to guide the PSA narrative as an abstract expression of water conservation connected to cultural tradition. This expressionist and contextualist viewpoint helped them advocate for social change using traditional aesthetic viewpoints, engaging cultural expression and transformation of the ancestral and cultural traditions of Native Americans, which was clearly brought in by NAAC students. Stewart, one of the SRU students, reflected on this.

Stewart: Cultural, yeah, I mean, I try to mostly leave that to the other group members. I mean, I definitely could see how we had some wardrobe, like you guys had the baskets and everything. Like the baskets were, like, symbolic of, you know, like, that tradition of, like, carrying water or, you know. But, like, I just tried to be on more of the technical side than the aesthetic side for this piece, I think.

Stewart’s hesitant speech conveys his limited participation in and understanding of the aesthetic decisions made.

**Finding a narrative amid team strife**

Although the team had a strong start aesthetically with their poem, it was clear that the team was struggling to work together. In a survey given in week two, Juan described the group dynamics:

Juan: The brainstorming is slow. Two members are quiet, and the other is gradually grasping the concepts that govern dome production. As for myself, I am trying not to take over the entire project and stifle the creativity of the others.

The following week, the team reached out to me for advice on how to build their narrative. Given this request paired with knowledge that the team was struggling to work together, I thought a game might present an alternative way for the students to express their ideas for the narrative, and let the quiet students have a voice. I adapted a game for them called Rory’s Story Cubes. I had them write down their favorite narrative ideas, one idea in each square. They cut out the squares and created cubes (Figure 5.23). Some sides
had images and others only included text. The cubes had a variety of ideas listed on them like, “water moving down gutters,” and “time-lapse of sunrise.” The cubes illustrated their ideas about the acts and what should happen in them, including some technical aspects, such as “simple dissolve to earth rotating.” Many of their ideas were very similar, but getting them to listen to each other was the more difficult task. This process allowed the students to share their ideas without any one person’s ideas dominating the narrative building process.

![Story Cubes](image)

Figure 5.22. Story Cubes

The students played the game for about 30 minutes, recording their ideas down on pieces of paper. I organized these on a master sheet and then the students had to vote on their favorite ideas (Figure 5.24).
This activity engaged the students in the story building process. The students were able to finish their narrative planning using a domemaster storyboard template (Figure 5.25).
Strife prevents technical learning and development

Although the team developed a clear vision for their PSA, and solved some basic dome production problems, they did not solve new technical problems related to the fulldome. This seems to be related to challenges they were not able to surmount. The SRU members were supposed to be paid on a regular basis, but for institutional reasons, their payment was delayed. A conflict arose between the two SRU students, Juan and Stewart. Juan, frustrated both by the delays in payments and teamwork issues, took several sick days and never returned. This left the team feeling like they were the “underdogs”; Juan was to fulfill an important technical role in the group—art director and CGI animator. His departure left a technical knowledge gap for the team. I reflected on these issues in week four in a blog post:

Group 2 had a difficult day, they were missing two of the four group members. This was the third day that one student had been gone, and quite
randomly a second student in their group was absent today. Unfortunately, the missing students not only neglected to contact their group mates in a timely manner, they also had vital equipment with them, which was needed at the lab. Unfortunately, I think the spirit of this group is also quite damaged as they had already suffered into week three without having a solid story for their PSA. After my work with them last week, they seemed much more inspired and confident about their ability to create a professional dome project. (June 20, 2013)

They had seemed so confident about their story and project the prior week, yet when I recorded this blog post, I had serious concerns about the lack of participation from the SRU students, Juan and Stewart. I further recorded in my blog:

Today two of my students from NAAC experienced great turmoil trying to pick up the pieces of the project and redesign them to be productive for the dome. They had to create the shot list for the green screen dancers, which until late today had not been solidified. Its [sic] been hard for them to be inspired to do all this themselves, because they don't have a lot of experience between the two of them with green screen videography techniques. (June 20, 2013)

Stewart and Juan had experience working in the green screen, so when neither showed up that day, the NAAC students struggled. I further noted in my blog:

This group is facing so many difficulties, I am very worried it is impairing their interest and desire to finish the project. I felt the stress of the students who were in class today and were left to figure it all out alone. I am really worried how the absences of half the group affect other students interest if some students give up or quit. I am just hopeful that this doesn't happen and that the other two students get well and return to the group as soon as possible. (June 20, 2013)

By the following week, team We are Water had learned Juan would not be returning to the internship. In my blog, I reflected on the situation, stating that the team:
has been seriously negatively effected [sic] in their drive to complete the project, their motivation to finish the job seems to have been seriously effected [sic] due to numerous absences from one of the lead students. Additionally, one of the students, in the group expressed to me that they had not been paid, and that because of the student employment situation and the lack of presence in the group, that his drive to finish the project was lacking. He was seriously broke and his presence and energy for completing the project have been very minimal. He wasn't taking the job seriously, he even planned a trip to Denver, missing this coming Thursday class, because he is not really caring about this project so much.

I really feel bad for the other two students from NAAC, they have put in a tremendous amount of effort to the project. Their ideas were ignored and overran [sic] by the SRU students who ended up quitting when the job got tough. The students from NAAC were patient, and constant, and had a great work ethic, showing up daily. I know one of the NAAC students also worked a weekend job, and hadn't had a day off since starting the internship. I can see how worried he is about this project on his face. I can see his worry of how his group has let him down. I worry about how these projects can sometimes led (sic) to less productive experiences for students, and instead guiding them away from the intended technology you wanted them to engage with originally. (June 24, 2013)

Stewart revealed how losing a team member impacted their ability to attempt technically complex domemaster construction.

Stewart: It kind of left a sour taste in my mouth that one of our team members basically abandoned us. […] That was hard to bounce back from. And not only that, but you know, we were down one member the whole time. So we were kind of the underdogs. […] So, and we didn't really have that on our team. We didn't really have a strong a CGI [computer-generated imagery] department.
The students made an aesthetic and technological decision to construct their PSA in a simpler way that maximized their media skills in their three-person team after Juan left the internship. They used the skills they had, without trying any challenging technical processes for producing dome content. The lack of teamness ultimately contributed to the team’s diminished STEM learning experiences, specifically problem solving and innovation.

Conclusion

Although Team We are Water delivered a completed PSA project, they did not engage in deep and meaningful STEAM learning. From interviews and documents collected from SRU team members I can infer the team did not research water conservation deeply. Although their PSA was loosely based on the science concept that humans are made mostly of water, they did not deliver that scientific idea in their PSA directly. Instead they used a metaphor through poetry to deliver that concept.

Although the team used technology to complete their project, they barely expanded their knowledge of dome production. They did not innovate dome production technology; they simply relied on previous technology skills they had, or skills they learned during the internship.

The lack of teamwork affected their ability to consider and solve complex technical problems of the dome. They mostly used tools and techniques they had already mastered and still barely finished the project.

The PSA they created used aesthetics to express an abstract metaphor about water conservation. They presented a contextualist and symbolic aesthetic message about water conservation, communicated through a poem and narrative they developed using a game.
CHAPTER 6: DISCUSSIONS, CONCLUSION AND IMPLICATIONS

Cross-case analysis

Starting from the project launch document, the two design teams approached production of the public service announcement differently. Each design team developed an aesthetic intent, and this drove them toward different production goals. Although each design team focused on social issues to build their narratives, their public service messages were distinct. A major contrast between the two design teams was their team dynamic and the degree to which they developed teamness; this affected how ambitious they were in tackling technical challenges. The teams’ divergent approaches to production of their PSAs directly impacted their STEAM learning.

Aesthetic intent drives STEAM learning

Team Rainwater Station made an aesthetic choice to produce their PSA with a specific aesthetic style that required the students to overcome technical problems of the fulldome. The technical problems they faced required novel application of their prior knowledge to express their intended aesthetic for the fulldome format. They created new techniques for designing cinematic fulldome productions, a clear expression of 21st century problem solving skills that particularly engaged technology, engineering, mathematics and art learning.

Students from Team Rainwater Station, participated in hands-on, real-world engineering experiences that motivated the students to learn STEM content and concepts, in a relevant problem-based scenario as suggested by (Erickson, 2013). Despite the fact that the science and math content wasn’t fully integrated into a successful STEAM design school experience, the students participated in problem-solving and critical thinking supporting 21st century innovation skills, because of their deep motivation and personal connection to the content subject, which is a critical part of the STEAM movement. As higher education looks to promote critical thinking and innovation, institutions are integrating art education across multiple disciplines to help students solve problems with design thinking (Platz, 2008).
In contrast, Team We are Water produced their PSA using traditional aesthetic designs, in which they applied their prior design knowledge, but did not innovate new ways to solve technology problems. They completed the minimum standards for fulldome production, using the skills within their diminished team. Their final design barely included reference to the science knowledge they were assigned to incorporate and research. Analysis of the interview with SRU student Stewart and of the final PSA makes it apparent that he did not connect deep and meaningful science learning during the project. Their aesthetic decisions, paired with team difficulties, hindered their STEAM learning and contributed to their limited STEM learning experience. Team We are Water did deliver a stylized metaphor about water and its relation to sustaining life, but the connection was not clearly delivered to the audience.

As Singer and colleagues (2000) suggest, students who participate in in-depth inquiry by collecting and analyzing data acquire the skills necessary to understand and communicate their results using the scientific process. Evidence collected from SRU students suggests neither design team participated in enough in-depth inquiry to actually understand and communicate much scientific data. Team Rainwater Station did solve ill-structured problems, providing them access to problem solving experiences (Jonassen, 2000), a 21st century skill. However, their research time was spent on solving technology design problems versus researching how to deliver science content in their PSA as assigned. The effectiveness of the design product, is the goal of design, and dependent on the well-crafted, aesthetic use of materials and tools to create a product (Lawson, 1997; Vande Zande, 2010), which the students didn’t fully achieve, because they did not deliver the scientific message, as assigned for their intended museum audience.

Social perspectives informed narrative development and missed science learning

Both design teams focused on societal issues as a context for their narrative development, although they approached the development of the narratives differently. From analysis of SRU students, it is apparent that both teams missed science learning opportunities embedded in the project. They focused on the social issues of water
conservation instead of science facts or concepts as requested in the project launch document.

This may have been a result of ineffective research techniques and lack of feedback targeting this issue during their design process. Instead, they focused on social issues to develop their narratives. The students brought contemporary context and personal meanings into their PSAs. For example, Team Rainwater Station brought contemporary context into their PSA by (1) using the topic of water as a scarce resource; (2) placing the little girl as the problem solver, in contrast to the culturally dominant ethno-aesthetic, which usually places men or boys as the problem solvers of technology or science. They used societal concerns about water conservation as a method to inform the public about rainwater collection and harvesting. Their narrative focused on contextualizing stereotypes of Native Americans and girls, instead of presenting a scientific point of view regarding water conservation as instructed by the project launch document.

Team We are Water also used societal concerns about the conservation of water as a cultural narrative for development of their PSA, creating a poem that presented cultural views of science connected to water conservation. They focused on an abstract metaphor of water conservation, expressing symbolic and ethno-aesthetic Native American cultural traditions, which brought a contemporary context into their PSA. For example, the inclusion of (1) the realist videos of water wasting; (2) the diversity of the dancers and the colors of the dancers and their shadows.

Neither team fully engaged the requirement of including scientific knowledge about water conservation. Instead, both design teams chose to focus on contextualizing their water conservation PSAs around societal concerns and issues, especially those with ethno-aesthetics. Team Rainwater Station ended their video with a simple call to action, stating the amount of rainwater which could be collected annually. Team We are Water also expressed a metaphorical call to action around water conservation through the poem narration, specifically the final slogan "Honor the earth, respect water, preserve life." However, from the final video, we can infer the focus on symbolic ethno-aesthetics and
abstract metaphor seems to have contributed to their limited STEM learning experience, especially with regard to science learning.

The ability to contextualize worldview while navigating technology is a clear connection to 21st century skill building (Mayo, 2007); however, in terms of STEAM education, there are clearly some missing pieces which hindered full integration of science education within the context of this internship. However, the students of We are Water did use metaphor to contextualize their worldview of water conservation, through their navigation of technology.

Lakoff and Johnson (1980) describe metaphor as “one of our most important tools for trying to understand what cannot be fully comprehended: our feelings, aesthetic experiences, moral practices, and spiritual awareness” (p.193). Metaphor is the primary substance of art education (Effland, 2002). It is clear the students benefited from the applied use of creative thought as suggested by Lowenfeld (1975) while creating their PSAs. However, the SRU students clearly did not fully connect science learning and understanding to their final projects.

**Teamness is a motivator for STEAM learning**

Collaboration and social interactions are important for group dynamics to be successful, and as suggested by (Brereton, Cannon, Mabogunje, & Leifer, 1996) and evident in data presented from each case. While Team Rainwater Station developed teamness, the other team did not. I propose that lack of teamness contributed to Team We are Water’s limited ability to solve design problems and ultimately hindered their engagement in authentic and meaningful STEA learning.

Analysis reveals that Team Rainwater Station participated in more STEM learning opportunities than Team We are Water because Team We are Water suffered from a lack of teamness. I argue that STEAM learning was only partially accomplished by Team Rainwater Station because they had a positive team dynamic which supported the cohesion of the group, allowing them to express their prior and applied knowledge, supporting their goal to build a cinematic stylized PSA film for the fulldome, through
which they engaged in an authentic and meaningful STEAM learning experience where they solved problems for immersive technology.

Table 6.1 below shows the themes that surfaced during analysis regarding the students' STEM and Art learning. What is most important in the table is that Team Rainwater Station is motivated, they get along and have teamness, and therefore they are motivated to solve technical problems of the dome. In contrast Team We are Water is not interested in solving technical problems of the dome. They have severe team dynamic problems and therefore they are just trying to get by, they don't have time to try to solve problems or even participate in research for their PSA topic.

Table 6.1 Cross-case comparison

<table>
<thead>
<tr>
<th>Team Rainwater Station</th>
<th>Team We are Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest in the topic</td>
<td>Not as much interest in the topic</td>
</tr>
<tr>
<td>Solved problems related to technology to accomplish aesthetic intent</td>
<td>Did not attempt to solve technology</td>
</tr>
<tr>
<td>Four team members active, engaged and committed during entirety of project</td>
<td>Only three final team members, with one of three team members not fully engaged or committed</td>
</tr>
<tr>
<td>Only one absence from one team member</td>
<td>Multiple absences from several team members</td>
</tr>
</tbody>
</table>

Team We are Water simply did not have the same learning opportunities in STEM, because they lacked teamness, team members and interest in the project subject, water conservation, as suggested from SRU student interviews.

Table 6.1 includes issues that affected the cohesiveness of Team We are Water, which ultimately contributed to their limited STEM learning experience. When students experience a lack of teamness, they miss opportunities for STEM and art learning, because they are less engaged in the learning experience and have less collective capacity to solve problems. Because the SRU members in Team We are Water experienced problems early in their team formation, it affected the team dynamics and ultimately their perception about the authenticity of the project and their ability to participate deeply. In contrast, the SRU members in Team Rainwater Station developed a strong dynamic early in the internship, and this supported their ability to expand learning opportunities by
solving technical challenges. Connor described his experience brainstorming with the group as very successful in an interview.

Connor: I felt that my group’s brainstorming progress was very successful. Each person had very interesting ideas regarding water conservation. My own personal ideas were interesting. [...] I believe that my job at Rehm's Nursery, a local garden center, and the connections that the store provides will greatly aid our water PSA project as it provided me with the information on the Water Harvest workshop, knowledge of native plants and access to water harvesting technology. I also believe that my interest in water conservation and earthships could (response ends abruptly).

This personal connection for Connor was instrumental in motivating him to participate, supporting the team’s goal of solving specific immersive technology problems that emerged from their aesthetic choices.

Discussion

The problems tackled by the teams were *ill-structured*, meaning they were emergent and unpredictable (Jonassen, 2000). The SRU members in Team Rainwater Station, solved the ill-structured problem of designing a realistic fulldome movie. In contrast, the SRU members in team We are Water did not attempt to solve any ill-structured problems during their design process.

As noted earlier, experienced designers tend to be more adept at solving ill-structured problems (Siegel & Stolterman, 2008). In this case, Team Rainwater Station appears more expert in their technical work, likely because the students collectively brought a larger skill set than Team We are Water. One of the SRU students in Team Rainwater Station had specific knowledge and skills in the use of green screen technology, and another had advanced skills using Adobe After Effects software; the
students leveraged these skills to solve the design problem of using videography in the fulldome as a cinematic aesthetic. They devised a way to shoot video using the green screen that would support the large format of the fulldome theater.

The students participating in this internship program had expanded opportunities for STEAM learning because of the authenticity of the project-based design problems they were asked to solve. Students solve immersive design problems when they build on previous design knowledge. The students were put into their design team because they had complementary skills in a variety of media disciplines, an approach endorsed by Fleischmann (2008). Team Rainwater Station took advantage of this approach, building on their varied skills to apply their prior knowledge creatively to solve design problems of the fulldome.

The expressive and aesthetic intent evolved for each case over the first couple weeks of the internship. Team Rainwater Station focused on a cinematic style of aesthetics that they chose to express using specific video graphic techniques that were difficult to accomplish without some innovative approaches to solving design problems. Their final design did not include a continuous narrative. The only speaking parts were the water bearer saying, "we ain't got no more water" and the little girl yelling "mom" at the end of the PSA. The soundtrack was minimal, with only the creaking of the sign in the beginning, the cicadas during the entirety of the PSA and sound of pouring and dripping water, which left the piece feeling incomplete.

In contrast, Team We are Water focused on the development of an abstracted narrative as their chosen aesthetic style for their fulldome PSA. Their final PSA presented a more complete soundtrack, with drumming, chanting, and narration of the poem they constructed. This guided the audience through a metaphorical abstracted message of water conservation. They used simpler techniques for creating fulldome media that didn't require solving complicated technical design problems. A possible reason for this was that the SRU members in team We are Water had poor team morale, and they ended up loosing one team member, and they didn’t have the time or confidence as a group to try new things.
The outcomes of successful collaboration are reliant on the ability of the students to collaborate effectively and build an effective team mentality referred to as teamness (Mercer, Goldaman, & Booker, 2006). However, effective cohesion of a team does not equate to superior design (Svihla, 2010) and although it is still possible for a design team to create an effective product without teamness, it is far less likely they will learn from the process (Mercer et al., 2006). Teams who develop an early cohesion in the design process, help develop a sense of belonging to a group, with similar goals (Mercer et al., 2008).

In a recent study of engineering students' participating in design teams, the role of collaborative interaction was explored for its effects on innovation (Svihla, 2010). The study looked at the role of teamness and team cohesion and how it informed their final designs. The participants of the study were senior biomedical engineering students who participated in a year-long capstone design class. Authentic, real-world design projects were assigned to several four-person design teams. Surveys, and instruments were collected and analyzed and field experts were called to score and judge the design plans created by the students. Researchers used a social network analysis to construe team relationships and collaboration between individuals. The results of the study concluded that cohesion relates to innovation and applied knowledge, and that teams which have greater cohesion especially in the final phase of the project, will be more innovative than those which struggle to have teamness. Team cohesion or teamness, is an important factor to consider when researching how design teams innovate. Successfully designing multidisciplinary design teams is essential because it fosters teamness and mimics professional industry design groups.

Personal connections can increase students’ interest in a subject (Darts, 2006). The SRU students in Team Rainwater Station seemed more connected to the subject of the project, an inference from interviews and surveys. One of the SRU team members had experience and prior knowledge of rainwater collection which seemed to increase his interest in the design projects subject matter. His access to specific props like the water barrel seemed to encourage their design process.
In contrast, the SRU students from team We are Water did not express as much interest in the subject which clearly reduced the groups connection to the subject of water conservation. Stewart expressed, his lack of interest in the subject of water conservation and suggested that this lack of personal connection to the subject, decreased his interest in the project, and affected the design teams morale negatively. The creative process is dependent on motivation (Hennessey, 2003).

Creativity and innovation are connected to the social world (e.g., John-Steiner, 2000; Sawyer, 2006; Hilliges et al., 2007) and creativity is “deeply social”; thus, the most significant and creative insights will arise from collaborative teams instead of solitary individuals creating and innovating (Sawyer, 2006). Because the SRU members in team We are Water were not well connected to the subject, it decreased their social connection to each other and the teams solidarity for the project waned, thus they collaborated less, their creativity was limited and they missed opportunities to innovate during the design process. I infer they also missed several STEAM learning opportunities, and instead focused on art skills they already had instead of learning new techniques for art production or new skills or knowledge in science, technology, engineering or mathematics.

Art can integrate with social activism in design (Vande Zande, 2010). In this case, both of the teams approached the project from a point of social activism, they constructed PSAs which reflected and promoted aspects of social change and activism around water conservation. For example, Team Rainwater Station focused on societal aspects of access to clean drinking water, and stereotypes of Native Americans and women. And Team We are Water focused on expressing a cultural narrative about the spiritual importance of water conservation to Native Americans. Each PSA attempted to express an abstracted idea about water conservation through their designs, despite their inability to connect these ideas effectively to science facts or concepts.

**Conclusion**

This study sought to understand how student design teams engaged STEM and art learning when designing for immersive technology. Students participating in the internship successfully completed fulldome projects, though their designs did not fully
meet the requirement of informing “the public about important plans, technologies, laws in water conservation and other issues involving sustainability. It needs to be done with grace, tact and without preaching. They need to be beautiful and informational” and “presented from a scientific point of view.” Neither PSA expressed STEM concepts or facts about water conservation from a scientific point of view to the intended audience in an integrated manner. Instead both design teams focused on creating successful designs for the fulldome, and neither team engaged the topic of water sustainability beyond surface level research.

Team We are Water completed the minimum technical requirements for the project, whereas Team Rainwater Station innovated new applications for fulldome videography, ultimately engaging them in additional opportunities for technology and engineering learning.

Designing for immersive technologies engaged technology, engineering and art learning by supporting students to build on and innovate prior skills. However, science and math integration were not fully successful, and would require additional scaffolding and feedback. Students need to find connections between subjects (Moore, 1903), therefore it is imperative for instructors to recognize how STEAM disciplines correlate (Breiner et al, 2012). For instance, finding that Stewart did not understand the project launch document enough indicates that having a group discussion about the project could have helped the students find connections between STEM and the arts. Referencing the project launch document at each peer review might also have helped the students refine their designs according to the requirements.

Supporting the success of design teams includes supporting them to function on teams with diverse skills. Poor team dynamics lead Team We are Water to lose a team member and to be less ambitious in tackling technical problems. In the future, I would add a workshop to the first day of teamwork to include time for the students to get to know each other better and build respect and empathy for each other through dialogue before deciding media production roles. This type of activity would promote a classroom environment of inclusion and discussion that could lead to creative learning and fostering teamness.
Limitations

The limitations for this study are complex. First and foremost, it was a small study (N = 4) at the start, ending with only three participants, and therefore not a very broad sample. All of the study participants were male, limiting the applicability of findings further. The collaborating institution was not included in the original IRB for this study, so data from NAAC were excluded from collection and research.

Additionally, although the researcher helped design the internship curriculum, the co-instructors for the internship were not cohesive in their application of lessons and teaching methods. This impacted the effectiveness of the STEM education that was introduced, specifically within the internship. For example, I taught the students to calculate the geometry of the Nodal Ninja for their spherical photography lesson. When one of the students approached one of my co-instructors, he directed the student to a website where he could use an online calculator instead of showing the student how to use simple math and parallax testing to achieve successful spherical panoramas using the Nodal Ninja. Because of a lack of cohesive curriculum implementation, this student lost that STEM learning opportunity.

The findings are from an internship, and therefore might not transfer to other educational settings.

Implications

Instructional

Implications must be considered tentative and are not generalizable, and should instead be considered for their possible application for further study. By teaching design of immersive media, students can gain valuable experience because it can challenge them to be creative in their transfer of knowledge from previous disciplines. The findings are not generalizable, and instead present an approach to understanding how student design teams learned to design for immersive technology.

One of the most important themes that has come from this case study is that educators also must be wary to not STEAMwash their instruction, such that students miss opportunities for deep and integrated STEM learning. Students in this internship were
asked to create PSAs based on science facts or concepts, and although the students did loosely base their PSAs on these requirements, none of the teams actually expressed complex STEM concepts about water conservation in their PSAs. Consistent feedback could be the key to ensuring students integrate the various STEM subjects with art. Additionally, instructors must be on the same page for instructional resources and lessons. Lesson Structure must be detailed and implemented by each instructor with the same approach, such as how to teach a specific piece of equipment.

The curriculum design must allow students space for inquiry. However, the curriculum must also guide the student to achieve specific learning goals that engage full integration of STEM subjects through the arts learning. Finding ways for students to connect, and work together effectively will be one of the most challenging aspects. Perhaps allowing them some authority to choose their design team members, or supporting dialogue sessions with team members might support this phase of instruction.

**Research**

Designing for immersive fulldome technology has not been the source of many educational studies, especially in terms of STEAM learning. Although not generalizable, the findings are transferable to other STEAM learning, design learning, and collaborative learning settings. STEAM education is gaining popularity and although the approach shows many great opportunities for STEM learning, more research is needed to understand how to integrate subjects together. This study contributes to this field by providing insight into how educators might provide structure for integrated STEM learning using authentic project based art and design learning as a platform for collaborative STEAM education and 21st century learning goals.
## LIST OF APPENDICES

### Appendix A  Schedule of weekly activities in the internship

<table>
<thead>
<tr>
<th>Week</th>
<th>Activities &amp; Assignments (Points assigned)</th>
<th>Resources Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 SRU</td>
<td>Survey #1, Quiz #1, Blog Posts &gt; panoramas and photogrammetry, readings (quote w/ response)</td>
<td>Computer Lab, Field photography equipment</td>
</tr>
<tr>
<td>2 NAAC</td>
<td>Survey #2, Quiz #2 Blog Posts &gt; green screen video (screen capture) &amp; sound recording, readings (quote w/ response)</td>
<td>Green screen studio, Video equipment, Sound studio, Computer Lab</td>
</tr>
<tr>
<td>3 NAAC</td>
<td>Survey #3, Quiz #3 Blog Posts &gt; Mayasphere (screen capture) description of process, problems, solutions, project descriptions, readings (quote w/ response),</td>
<td>Computer Lab, Field photography equipment</td>
</tr>
<tr>
<td>4 NAAC</td>
<td>Survey #4, Quiz #4 Blog Posts &gt; After Effects (screen capture) and discussion of use in project, project descriptions phase, current what’s next, *PSA project synopsis (2pgs)</td>
<td>Computer Lab, Field photography equipment</td>
</tr>
<tr>
<td>5 SRU</td>
<td>Survey #5, Quiz #5 Blog Posts &gt; Process (screen capture) discuss problem solving, project descriptions and accomplished tasks. *Technology Rider for PSA versions (2pgs)</td>
<td>Computer Lab, Field photography equipment</td>
</tr>
<tr>
<td>6 SRU &amp;</td>
<td>Survey #6, Quiz #6 Blog Posts &gt; Final Project (screen capture) description about collaboration and problem</td>
<td>Computer Lab, Field photography equipment</td>
</tr>
<tr>
<td>NAAC solving &amp; movie link or upload, project descriptions, *Final Movie 30–90 seconds group project &amp; submission.</td>
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<tr>
<td>Date</td>
<td>Class Description</td>
<td>Reading Assigned</td>
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<tr>
<td>May 28</td>
<td>1. Presentation of SRU &amp; NAAC fulldome resources</td>
<td>Schorcht – <em>The basics of fulldome</em></td>
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<tr>
<td></td>
<td>2. Class / internship requirements</td>
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<td></td>
<td>3. Research (Dr. Svihla) &amp; Jane Crayton</td>
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<td></td>
<td>4. Project Launch Document – IMERSA PSAs</td>
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<td></td>
<td>5. Survey &amp; Quiz</td>
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<td></td>
<td>6. Blog Creation</td>
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<td></td>
<td>7. Group Formation - Initial meeting and brainstorming</td>
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<tr>
<td>May 29</td>
<td>• Dome forensic</td>
<td>Howe – <em>Flight of the pixel</em></td>
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<tr>
<td></td>
<td>• PSA – viewing / research</td>
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<tr>
<td></td>
<td>• Group – story building</td>
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<tr>
<td></td>
<td>• Group – HDR Spherical Panoramas</td>
<td></td>
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<tr>
<td>May 30</td>
<td>• Dome forensic continued</td>
<td>Lantz – <em>Large-scale immersive displays for entertainment and education</em></td>
</tr>
<tr>
<td></td>
<td>• Jane on research methods, fulldome storyboarding, building your pitch</td>
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<tr>
<td></td>
<td>• Processing HDR Spherical Panoramas Photomatix Pro and PT-gui</td>
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<tr>
<td>May 31</td>
<td>• Dome forensic of process and style</td>
<td>Remann – <em>Janus 2.0 - God of fulldome</em></td>
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<tr>
<td></td>
<td>• Field Practice (Spherical Photography)</td>
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<td></td>
<td>Group PSA shot-list development</td>
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<tr>
<td>June 3</td>
<td>• Intro to NAAC dome</td>
<td>Fraser – <em>Film and digital dome convergence: a reality check</em></td>
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<tr>
<td></td>
<td>• Peer Review Pitch #1</td>
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<td></td>
<td>• Discussion – who is the customer?</td>
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<td></td>
<td>• Survey &amp; Quiz</td>
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<td></td>
<td>• Group – concept review and revision</td>
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<td></td>
<td>• Intro to Video</td>
<td></td>
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<tr>
<td>June 4</td>
<td>• Group work, listing technology to be used, research on topic and themes, storyboards</td>
<td>Petersen – <em>The unique role of the planetarium / science center in science education</em></td>
</tr>
<tr>
<td></td>
<td>• Video Shoot (water tap)</td>
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<tr>
<td>June 5</td>
<td>• Dome works of NAAC review and critique discussion of aesthetics</td>
<td>Lantz – <em>Planetarium of the</em></td>
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<tr>
<td></td>
<td>• Video shoot on campus</td>
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<tr>
<td>Date</td>
<td>Activities</td>
<td>Notes</td>
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<td>------------</td>
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<td>--------------------------------------------</td>
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<tr>
<td>June 6</td>
<td>• Final Cut Pro lesson</td>
<td>future</td>
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<tr>
<td></td>
<td>• Group – storyboard and shot list re-development</td>
<td></td>
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<tr>
<td></td>
<td>• Intro to Green Screen</td>
<td></td>
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<tr>
<td>June 6</td>
<td>• Dome demos on immersive sound</td>
<td>Emmart – Tools and techniques for real-time dome production and education</td>
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<tr>
<td></td>
<td>• Intro to sound equipment</td>
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<td></td>
<td>• Group – sound production</td>
<td></td>
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<td></td>
<td>• Group finalizing shot lists and storyboards</td>
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<tr>
<td>June 10</td>
<td>• Peer Review Pitch #2</td>
<td>Ziche – Fulldome 3D for Everyone part 1/5</td>
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<tr>
<td></td>
<td>• Discussion – what makes a successful PSA?</td>
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<td></td>
<td>• Surveys and Quiz</td>
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<td></td>
<td>• Group – reassess shot-list and storyboard</td>
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<td></td>
<td>• Intro to MayaSphere</td>
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<tr>
<td>June 11</td>
<td>• Field Shooting</td>
<td>Ziche – Fulldome 3D for Everyone part 2/5</td>
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<tr>
<td></td>
<td>• Lab processing</td>
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<td></td>
<td>• Intro to Animating the MayaSphere</td>
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<tr>
<td>June 12</td>
<td>• Field Shooting</td>
<td>Bradbury – Fulldome 3D for Everyone part 3/5</td>
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<td></td>
<td>• Lab Processing</td>
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<td></td>
<td>• Intro to Photogrammetry and 123D Catch</td>
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<td>• Group – shooting and editing plans</td>
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<tr>
<td>June 13</td>
<td>• Field Shooting</td>
<td>Bradbury – Fulldome 3D for Everyone part 4/5</td>
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<td></td>
<td>• Lab Processing</td>
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<td></td>
<td>• Group planning, revisions</td>
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<td></td>
<td>• Photogrammetry into MayaSphere</td>
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<tr>
<td>June 17</td>
<td>• Peer Review Pitch #3 in dome</td>
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<td>• Survey and quiz</td>
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<td>• Group planning and revisions per review</td>
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<tr>
<td></td>
<td>• Introduction to After Effects</td>
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<tr>
<td>June 18</td>
<td>• Field Shooting</td>
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<td>• Lab Processing</td>
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<td>• Group planning and revisions</td>
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<td>• After Effects Animation</td>
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<td>June 19</td>
<td>• Field Shooting</td>
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<td>• Lab Processing</td>
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<td>June 20</td>
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<td>• Group planning and revisions</td>
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<td>• PSA Project Synopsis Due &amp; presented to group</td>
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<td>June 24</td>
<td>• Peer Review Pitch #4 in Dome with invited group for feedback</td>
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<td>• Surveys and quiz</td>
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<td>• Group meeting to revise PSA plans</td>
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<td>• Field Shoot</td>
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<td>June 25</td>
<td>• Group meeting to revise PSAs</td>
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<td>• Field or lab time per group needs</td>
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<td>• Extended afternoon Field Shoot Group B</td>
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<td>June 26</td>
<td>• Group meeting to revise PSAs</td>
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<td>• Field or lab time per group needs</td>
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<td>• Extended afternoon Field Shoot Group A</td>
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<td>June 27</td>
<td>• Group meeting to revise PSAs</td>
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<td>• Extended afternoon Field Shoot as needed</td>
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<td>• Technology Rider due and presented to group/class</td>
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<td>July 1</td>
<td>• Last chance to fix it Viewing in dome</td>
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<td>• Lab time as needed</td>
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<td>July 2</td>
<td>• Lab time</td>
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<td>• Semi-public viewing in dome</td>
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<td>July 3</td>
<td>• Presentation of Projects at SRU</td>
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<td>• Presentation of Promotional Materials to group</td>
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<td>• Uploading to FDDB</td>
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<td>• Send final 4K with technical rider to IMERSA</td>
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Appendix B  Nodal Ninja calculation sheet

Example diagram shows how to calculate the number of images to expose and what degree to rotate the Nodal Ninja tripod head for each degree of altitude.

Number of Images at each latitude layer with an 18mm lens.

1 = 8
2 = 12
3 = 18
4 = 24
5 = 18
6 = 12
7 = 8

Equation examples for half the dome.
1 = 360 / 45 = 8
2 = 360 / 30 = 12
3 = 360 / 20 = 18
4 = 360 / 15 = 24

Check your calculations by shooting the center strip of the panorama with their lens to test how many images must be shot with 10% overlap on the right and left side of each image across the horizon of the sphere. This will give you a baseline number to calculate and find the degrees to set the Nodal Ninja, from there you can use the same process to calculate how many latitude layers will be needed with 10% overlap on top and bottom of the images. This should be checked manually by the student and confirmed by using the simple math formula above.
Appendix C  Surveys and Interview questions

Week 1 Survey

1. Explain and describe the immersive environment using words and a hand drawn image?

2. What do you see as the biggest challenges for creating an immersive PSA?

3. What is the role of science, technology, engineering and/or math in solving these challenges?

4. What do you need to know and what do you need to know how to do in order to create your PSA?

Week 2 Survey

1. Explain the parallax problem and the effect it has on images. Explain how the Nodal Ninja can be used to solve this problem. How is it different from the Gigapan?

2. What are the differences between the nodal ninja and the Gigapan?

3. How would you describe your group’s brainstorming process and your participation in this activity?

4. How might your personal experiences, histories or connections reflect on your project.

5. What skills did you learn last week?
   a. What helped you learn those skills?

6. What skills do you need to learn?

7. What help do you need to learn them?

Week 3 Survey

1. Describe how masking layers in Photoshop can emphasis parts of the story. Provide an example.
2. Explain how and why the fulldome plug-in is used in the After Effects application.
3. Describe how to shoot video using a DSLR camera.
4. What settings in the camera must you be mindful of. Why?
5. What After Effects techniques did you learn last week, and which are you thinking to apply in your PSA? Why?
6. What changes to your shot list, or field shooting plan do you need to incorporate after the test exercise last week?
   a. What went wrong?
   b. What went right?
   c. What do you need to change?
   d. What new idea or technique do you want to replicate?

Exit Survey

1. At what rank would you rate the level of Authenticity of the project?
   Level of Authenticity  
   1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 - 10

2. Did that level of authenticity affect the technical quality? Yes / NO
   Level of Technical Quality  
   1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

3. Would the technical quality likely be lower if the project appeared to be less authentic? Yes / NO

4. How personally relevant was the project?
   Level of Personal Relevance  
   1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 - 10

5. Did that level of relevancy affect the depth and quality of narrative development by your team? Yes / NO
6. Please rate the level of Narrative Development your team accomplished.
Level of Narrative Development 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Interview Questions

Was the project authentic?

Project Launch Document?

How did you start the project?

How did you come up with ideas?

Technical quality of the project? Did it reflect industry standards?

Team make-up, do you think it reflected industry standards?

Tell me about your team, and what it was like working in a multidisciplinary team?

What kinds of skills did you have that were different from your team?

How did your skill set compliment the greater project?

How do you feel about the success of your project?

Do you think the diversity of skills on your team is reflective of what you might see in a professional dome production studio?

Can you describe to me a design problem your team encountered?

What kind of technical problems did your team have to solve?

What technology did you use, or learn to solve them?

How did your team collaborate to solve problems? tell me about their roles, or a specific example.
Can you describe to me a time where your team had to make aesthetic choices?

Can you describe that moment?

What happened to bring about that choice or need for an aesthetic decision?

What was the result of applying that aesthetic change?

Was it as intended?

Did you get an opportunity to refine your aesthetics after group criticism?

What did you do differently?

(ideas: rain barrel view of little girl looking in, Green screen boom?)

How personally relevant was the narrative to you, or your personal experiences?

Did that personal relevance provide you with motivation to participate in project?

How did you engage in STEM learning during the internship?

What STEM concepts did you learn?

What STEM careers did you learn about?

Did participation in the workshop influence or change any career interests for you?

How do you think your fellow students personal relevance played a role in their motivation to participate?
Appendix D  Team Rainwater Station - Brainstorming document

Desert shot w little water
Conservation of water in action—pueblo planting
Spot planting spot watering
Using communities—using kids in PSA
Water rights—who own the water
Harvesting, recycling
How to plan for water usage from hill to valley
Little efforts create a large effect
Life
Trees nature affected from rain and water cycles
Soil detrition
Rain and water cycles
How dams effect water usage and effects environment
Natural simulation of water destructive with dams
Consumption and how we consume water—grasses, snow
No proper understanding how to use water in proper manner
Change the way how we interact with environment
Just put up another dam so we have water - no good way
Put snow on peaks, santa fe put water on tops of mountains to make snow
Psa general area third world countries how they struggle to find drinking water we will end up there too
Global warming and how that effect
Water underground levels, groundwater, history leaky faucets, swamp cooler, car washes, grass watering, how live stock uses water
How we irrigate to grow more crops
Contamination from outside local population
Dying of dehydration
Contrast desert and water, how to make seat water from salt water
Problem with black mesa planting that doesn’t work
Water filtration system—non potable water don’t drink
Change the way people think about water—America a vast country people move around people don’t think about what can grow where Phoenix vaste water on grass lawns NM use to have grass lawns not so much anymore The more people the more water consumption Economy has impact on water usage and wasting water save money from saving water Tax deduction for saving water Metric tons of water to be allow Texas get most of water rights from rio grande Environmental effects—extinct fish animal life Circle of life if we loose one thing how does that effects next part in chain Chain reaction Visualize how things effects each other Rain chains how water trickles down how is water allocated Where does water go after we use it at home The cycle of water from home > rio grande > texas > ocean Audience part of problem get audience feel the impact Water goes down the drain and then we follow it to where it goes Showing cycle making it very obvious boring showing diagram of things Impact utilize shot of river, snow runoff from mountains Every day consumer of water tap toilet in house water source, lawn getting watered where does the water go? Water plant can smell from miles away—they take solids out of water, toilet, paper…. Put it in compost, sort solid waste, goes through chlorine charcoal, skim off water then it goes into the rio grande. How much energy goes into processing of water? You can drown in dirty water at plant Permaculture research Water by the number in NM Floods in patuka ohio river
Appendix E  Team Rainwater Station - Water harvest PSA initial research

Research:
EarthSystems

Rain water .623 gallons/sq. ft/inch of rain

Over the past 30 yrs, the avg annual Abq rainfall is 9 inches


Brad Lancaster, Waterharvesting.com
—Leader in water management
Great Interview
https://www.youtube.com/watch?v=4aQrZtG-LVg

Native Plants—Water Plants
Appendix F  Team Rainwater Station - Non-profit groups research

Websites:

Santa Fe Water Conservation initiative

Occupy New Mexico—Environmental Justice org

National Tribal Environmental Council—Here in ABQ

Southwest Network for Environmental Justice & Economic Justice—resource page (PDFs)

Permaculture Institute and their document archive page on water conservation and permaculture

Environment New Mexico—Our Water, Our Future program

Documents:

Youth organizing in Environmental Justice movement

Designing with Nature: Natural Systems for Wastewater Treatment—A how to document

Wasting Our Waterways 2012: Toxic Industrial Pollution and the Unfulfilled Promise of the Clean Water Act - report by Environment New Mexico
Appendix G  Team Rainwater Station - Shot List: Green Screen Day

2a - Characters 1-5 Waiting in Line - Long Shot

Shot Description:
Characters 1, 2, 3, 4, and 5 are carrying their buckets, waiting in line for water rations. The characters appear tired, depressed, and antsy waiting for water rations.

Shot Setting
- Table: Spot 1 (2a on gaffing tape)
  1. Characters in Shot (GoPro in mind):
     1, 2, 3, 4, 5, 6, 7, 8, 9, 10, Dusty
  2. Gap of 3-4 feet between characters 1 & 2
  3. 5 Buckets for talent
  4. Tablet & scanner on table (note position on table from last shot)
  5. Dusty’s water container on table with ladle in it (note position of ladle)

Camera
6. Focal Length: 18mm
7. Camera Tilt: Level
8. Shot: Long
9. Tripod Height: One leg up
10. Settings in Camera: 1/60, 100 ISO, 5100K, f 3.5
11. Camera Position: Stays at “cam 2a”
12. Movements: Camera is stationary

Lights
13. Lights stay in same position and setting (see “lighting” setup page) until shot 10
Talent
14. make natural slow movements
15. shuffling feet or shifting feet
16. appear tired of waiting (not angry, more depressed and antsy)

3 - Characters 1-5 Waiting in Line - Medium Shot

Shot Description:
Characters 1, 2, 3, 4, and 5 are carrying their buckets, waiting in line for water rations. The characters appear tired, depressed, and antsy waiting for water rations.

Shot Setting
• NO table
• NO Dusty
• 3-4 foot gap between character 1 and 2
• 5 Buckets for talent
• Dusty’s water container on table with ladle in it (note position of ladle)
• Tablet & scanner on table (note position on table from last shot)
• Characters in Shot: 1, 2, 3, 4, 5

Camera
1.0 Focal Length: 35mm
2.0 Camera Tilt: Level
3.0 Shot: Medium
4.0 Tripod Height: One leg up
5.0 Settings in Camera: 1/60, 100 ISO, 5100K, f 3.5
6.0 Camera Position: Stays at “cam 2a”
7.0 *Movements:* Camera is stationary

**Lights**
- Lights stay in same position and setting (see “lighting” setup page) until shot 10

**Talent**
1. make natural slow movements
2. shuffling feet or shifting feet
2. appear tired of waiting (not angry, more depressed and antsy)

**5 - Characters 1-2 In Line Getting Water Ration - Long Shot**

**Shot Description:**
Characters 1 and 2 are carrying their buckets, waiting in line for water rations. The characters appear tired, depressed, and antsy waiting for rations. Water man has them scan their barcodes for rations. Character 1 gets water and exits shot, character steps up to table as character 1 begins to leave.

**Shot Setting**
1. Table: Spot 1 (2a on gaffing tape)
2. 3–4 foot gap between character 1 and 2
3. 2 Buckets for talent
4. Tablet & scanner on table (*note position on table from last shot*)
5. Dusty’s water container on table with ladle in it (*note position of ladle*)
6. Characters in Shot: 1 and 2, Dusty

**Camera**

1. *Focal Length:* 24mm OR 18mm depending on what looks best
2. *Camera Tilt:* Level
3. *Shot:* Long
4. *Tripod Height:* One leg up
5. *Settings in Camera:* 1/60, 100 ISO, 5100K, f 3.5
6. *Camera Position:* Stays at “cam 2a”
7. *Movements:* Camera is stationary

**Lights**

- Lights stay in same position and setting (see “lighting” setup page) until shot 10

**Talent**

- Make natural slow movements (shuffling feet or shifting feet)
- Appear tired of waiting (not angry, more depressed and antsy)
- Character 1 puts fist under scanner (slower movement)
- Dusty looks at tablet to verify bar code was accepted
- Character 1 puts bucket (or canteen) on table for dusty to fill
- Dusty pretends to fill bucket or canteen with ladle
- Character 1 turns to leave (walk toward camera)
- As character 1 turns to leave, character 2 steps up to table

4 - Characters 2-3 In Line & Getting Water Ration - Over Shoulder Shot
Shot Description:

Characters 2 and 3 are carrying their buckets, waiting in line for water rations. The characters appear tired, depressed, and antsy waiting for water rations. Water man has them scan their barcodes for rations.

Shot Setting

5. Table: Spot 1 (2a on gaffing tape)
6. 3–4 foot gap between character 2 and 3
7. 2 Buckets for talent
8. Tablet & scanner on table (note position on table from last shot)
9. Dusty’s water container on table with ladle in it (note position of ladle)
10. Characters in Shot: 2 and 3 and Dusty

Camera

3. Focal Length: 24mm
4. Camera Tilt: down (level for an alternate shot)
5. Shot: Long
6. Tripod Height: 69.5 inches from bottom of camera (lower height for an alternate shot)
7. Settings in Camera: 1/60, 100 ISO, 5100K, f 3.5 (f-stop may change in new camera position, use settings you figured out earlier today for this shot)
8. Camera Position: Moves to “cam 4”
9. Movements: Camera is stationary.
Lights

1. Lights stay in same position and setting (see “lighting” setup page) until shot 10

Talent

2. Make natural slow movements (shuffling feet or shifting feet)
3. Appear tired of waiting (not angry, more depressed and antsy)
4. Character 2 puts fist under scanner (slower movement)
5. Dusty looks at tablet to verify bar code was accepted
6. Character 2 puts bucket (or canteen) on table for dusty to fill
7. Dusty pretends to fill bucket or canteen with ladle
8. Character 3 turns to leave (exit right)
9. As character 2 turns to leave, character 3 steps up to table

6 - Character 3 Getting Water Ration - Over Shoulder Shot

Shot Description:

Character 3 is carrying his bucket, waiting in line for water ration. The character appears tired, depressed, and antsy waiting for water rations. Water man has character 3 scan his barcode for ration.

Shot Setting

1. Table: Spot 1 (2a on gaffing tape)
2. 1 Bucket for Character 3 and 4
3. Tablet & scanner on table *(note position on table from last shot)*
4. Dusty’s water container on table with ladle in it *(note position of ladle)*
5. Characters in Shot: Character 3 and 4, Dusty

Camera

1. *Focal Length*: 35mm
2. *Camera Tilt*: down (level for an alternate shot)
3. *Shot*: Long
4. *Tripod Height*: 69.5 inches from bottom of camera (lower height for an alternate shot)
5. Settings in Camera: 1/60, 100 ISO, 5100K, f 3.5 (f-stop may change in new camera position, use settings you figured out earlier today for this shot)
6. *Camera Position*: Stays at “cam 4”
7. *Movements*: Camera is stationary

Lights

1. Lights stay in same position and setting (see “lighting” setup page) until shot 10

Talent

2. Make natural slow movements (shuffling feet or shifting feet)
3. Appear tired of waiting (not angry, more depressed and antsy)
4. Character 3 puts fist under scanner (slower movement)
5. Dusty looks at tablet to verify bar code was accepted
6. Character 3 puts bucket (or canteen) on table for dusty to fill
7. Dusty pretends to fill bucket or canteen with ladle
8. Character 3 turns to leave (exit right)
9. As character 3 turns to leave, character 4 steps up to table
Shot Description:

Character 4 steps up to the table carrying his bucket for water ration. The character appears tired, depressed, and antsy waiting for water rations. Water man says he’s “out of water” when character 4 approaches table.

Shot Setting

1. Table: Spot 1 (2a on gaffing tape)
2. 1 Bucket for talent
3. Dusty’s water container on table with ladle in it (*note position of ladle*)
4. Tablet & scanner on table (*note position on table from last shot*)
5. Characters in Shot: 4 and Dusty

Camera

1. *Focal Length:* 24mm
2. *Camera Tilt:* Level
3. *Shot:* Medium
4. *Tripod Height:* 72 inches
5. Settings in Camera: 1/60, 100 ISO, 5100K, f 3.5 (f-stop may change in new camera position, use settings you figured out earlier today for this shot)
6. *Camera Position:* Move to “cam 7”
7. *Movements:* Camera is stationary
Lights

1. Lights stay in same position and setting (see “lighting” setup page) until shot 10

Talent

2. Make natural slow movements (shuffling feet or shifting feet)
3. Appear tired of waiting (not angry, more depressed and antsy)
4. Character 4 steps up to the table, beginning to raise bucket
5. Dusty says, “sorry, out of water” to character 4 and waiting line
6. Disappointed character 4 puts bucket (or canteen) down slowly then turns right (to camera) to exit shot

10 - Characters 4-10 - No More Water - Wide Shot

Shot Description:

Character 4 steps up to the table carrying his bucket for water ration. The character appears tired, depressed, and antsy waiting for water rations. Water man says he’s “out of water” when character 4 approaches table. Characters 4-8 begin exiting scene. Characters 9 and 10 linger in shot.

Shot Setting
• Table: Spot 1 (2a on gaffing tape)
• 3-4 foot gap between character 4 and 5
• 7 Buckets for talent
• Tablet & scanner on table (note position on table from last shot)
• Dusty’s water container on table with ladle in it (note position of ladle)
• Characters in Shot: 4, 5, 6, 7, 8, 9, 10, Dusty

Camera

• Focal Length: 18mm
• Camera Tilt: Level
• Shot: Wide
• Tripod Height: 69.5 inches
• Settings in Camera: 1/60, 100 ISO, 5100K, f 3.5 (f-stop may change in new camera position, use settings you figured out earlier today for this shot)
• Camera Position: Moves to at “cam 10”
• Movements: Camera is stationary

Lights

1. Move light #99 to new position

Talent

2. Make natural slow movements (shuffling feet or shifting feet)
3. Appear tired of waiting (not angry, more depressed and antsy)
4. Character 4 steps up to the table, beginning to raise bucket
5. Dusty says, “sorry, out of water” to character 4 and waiting line
6. Disappointed character 4 puts bucket (or canteen) down slowly then turns right (to camera) to exit shot
7. Characters 5-9 non-verbally communicating (couples giving each other looks) their
disappointment to each other and begin to slowly exit to camera
8. Dusty turns (with tablet) to enter his shack just as 9 is exiting.
9. 9 turns back to look at daughter

12 - Character 10 - Makes Discovery - Wide Shot

Shot Description:
Character 10 (little girl) follows black hose to rain barrel. She walks up steps
to rain barrel and peers into it. It begins to rain. She studies the rain for a
moment, then makes a discovery!

Shot Setting
1. Table: Spot 2 (12 on gaffing tape)
2. Dusty’s water container on table
   with ladle in it (note position of ladle)
3. Characters in Shot: 10
4. Add black hose between rain barrel and water faucet near table
5. Rain barrel with steps up to the barrel

Camera
1. Focal Length: 18mm
2. Camera Tilt: Level
3. Shot: Wide
4. *Tripod Height:* 48.5 inches (kid level)

5. Settings in Camera: 1/60, 100 ISO, 5100K, f 3.5 (f-stop may change in new camera position, use settings you figured out earlier today for this shot)

6. *Camera Position:* Moves to at “cam 12”

7. *Movements:* Camera is stationary

**Lights**

1. Keep light #99 in new position

**Talent**

2. Wet character 10 for rain simulation

3. Character 10 makes natural slow movements as she curiously follows black hose from faucet to rain barrel.

4. Character 10 steps up to rain barrel and peers in (stay peering for 5 seconds, then look surprised and say “mom!”)

13 - Characters 10 - Makes Discovery - Close-up

**Shot Description:**

Character 10 (little girl) peers into rain barrel. It begins to rain. She studies the rain for a moment, then makes a discovery! Girl is at zenith of dome.

**Shot Setting**
1. Characters in Shot: 10
2. Rain barrel with steps up to the barrel

Camera

1) Focal Length: GoPro
2) Camera Tilt: Level
3) Shot: Close-up
4) Tripod Height: GoPro in barrel
5) Settings in Camera: (use settings you figured out earlier today for this shot)
6) Camera Position: Stays at “cam 12”
7) Movements: Camera is stationary

Lights

1) Keep light #99 in new position

Talent

2) Wet character 10 for rain simulation
3) Character 10 steps up to rain barrel and peers in (stay peering for 5 seconds, then look surprised and say “mom!"

8 - Dusty Pours Water - Close-up

Shot Description:
Dusty turns ladle upside down and water drops (cgi) from ladle. Ladle will be at zenith of dome.

Shot Setting

1) Characters in Shot: Dusty’s arm
2) Need ladle for Dusty

Camera

1) *Focal Length:* 35mm
2) *Camera Tilt:* Level
3) *Shot:* Close-up
4) *Tripod Height:* whatever works for shot
5) *Settings in Camera:* use settings you figured out earlier today for this shot
6) *Camera Position:* Move where it works
7) *Movements:* Camera is stationary

Lights

1) Move lights for best shot

Talent

2) Dusty turns ladle upside down and water drops (cgi) from ladle.
Appendix H  Team We are Water - Brainstorming document
May 28, 2013

Animated hieroglyphs shadows moving around dome 2d animated figures
Palces to shute snake moving through desrt
Slow camera
Stop motion on dry ground scorched earth comes back to life
Underwater 360 panorama GoPro
Underground aquifer animation drying up
Go through tunnels like aquifers
Indian ceremony to do with water
Wells, deserts, rivers, near town life, water animation, graffiti arts-light photography
Images of drying up rivers rio grande sana fe river juxtapose metropolitan elements 360 footage
Desert landscapes, golf courses, city scapes, livestock, animal farms, dirt frams, representation of 3 cultures Anglo, Spanish native am.
Sunsets, fountains, CG global and oceanic animation
Rivers, lakes, various water sources, use of water in daily activities, gardening, recycling water, rain water and clouds, drying rivers, drought and fire hazards, irrigation and agriculture, naked mountains burn, loss of habitat
How we conserve water, how much water we conserve in daily life, how much water we use as individuals and communities, corporations and they drain out lakes and rivers in communities and how that can be a problem fro communities.
Importance of water recylce, how communities can be more sustainable with food, water, how comm. Different spiritual/ceremonies for water praying in local communities.
Protecting water resources, agriculture
Identifying the problem, concept of water conservation and sustainability. Sustainabilty recycling water,
go from outside into aquifer.
Each cycle of water cucle starting from aquifer, evaporating to clouds, transportation from lake to trees to coulds to precipitation, back in to to aquifer and so on
Create spherical panorama from water cycle

Parallel natural cycle and man made recycling processes of water. Put in native american spiritual aspect to measure the importance of water. Farmers in Spanish communities plants chilies

Local element global perspective?

Tie water cycle to farming. Sustainability to use land and recourses and how water cycle is important

Cycle of any local community affects other communities all over the world.

360 photo is a cycle of pictures…
narration as a poem a poem about water, water cycles,
start uot on local level with poem, then cycle of plants,
start of with payer that start of pray for ocean people and people around oceans.

Flowers from native American birth. Group the traditional dances. Record or take pictures. Dance with green screen panorama of river bed.
Appendix I  Team We are Water - Storyboard
Sustain the world. Respect and honor the earth.
Appendix J  Team We are Water Shot list: Green Screen Day 6-20-13

Shot List: Green Screen Day 6-20-13

3a – Dancers 1, 2, 3 will all be standing in a line - Long Shot

Shot Description:
Dancers 1, 2, 3 are standing in a line, as they hear the first few drum beats dancer one will pick up her basket and lift it up to the East. As she lifts up her basket dancer 2 will kneel to pick up her basket and lift up.

Shot Setting
- Dancers in Shot (GoPro in mind): 1, 2, 3
- Gap of 4-5 feet between dancers 1, 2, 3
- 3 Baskets in front of each dancer
- Some drums spread out across the set

Camera
- Focal Length: 18mm
- Camera Tilt: Level
- Shot: Long
- Tripod Height: One leg up
- Settings in Camera: 1/60, 100 ISO, 5100K, f 3.5
- Camera Position: Stays at “cam 2a”
- Movements: Camera is stationary

Lights
- Lights stay in same position and setting (see “lighting” setup page)

Talent
- make smooth slow movements with the baskets
  - shuffling feet or shifting feet
3 – Dancers 1 and 2 honor the North - Long Shot

Shot Description:
Then slowly dancer 1 will begin to sway her basket to the left towards the North and lifts up. As she is swaying dancer 2 will get into her next position to the left and lift her basket to the left

Shot Setting
• Dancers in Shot (GoPro in mind): 1, 2, 3
• Gap of 4-5 feet between dancers 1, 2, 3
• 3 Baskets in front of each dancer
• Some drums spread out across the set

Camera
• **Focal Length**: 35mm
• **Camera Tilt**: Level
• **Shot**: Medium
• **Tripod Height**: One leg up
• **Settings in Camera**: 1/60, 100 ISO, 5100K, f 3.5
• **Camera Position**: Stays at “cam 2a”
• **Movements**: Camera is stationary

Lights
• Lights stay in same position and setting (see “lighting” setup page) until shot 10

Talent
• make natural slow movements
  • shuffling feet or shifting feet
• appear tired of waiting (not angry, more depressed and antsy)
5 – Dancers 1,2 and 3 honor the south- Long Shot

**Shot Description:**
As dancer 2 lifts her basket up, dancer 3 will kneel and pick up her basket. Dancers 1 and 2 will slowly begin to sway their baskets to the right. As they are swaying, dancer 3 will begin to walk to her position on the right and lift her basket towards the south.

**Shot Setting**
Stays the same

**Camera**
- **Focal Length:** 24mm OR 18mm depending on what looks best
- **Camera Tilt:** Level
- **Shot:** Long
- **Tripod Height:** One leg up
- **Settings in Camera:** 1/60, 100 ISO, 5100K, f 3.5
- **Camera Position:** Stays at “cam 2a”
- **Movements:** Camera is stationary

**Lights**
- Lights stay in same position and setting (see “lighting” setup page) until shot 10

**Talent**
Stays the same
4 – Dancer 1, 2, and 3 turn around and honor the south – Long Shot

**Shot Description:**
Slowly dancers 1, 2 and 3 will turn around to face the west towards the screen.

**Shot Setting**
Stays the same

**Camera**
- **Focal Length:** 24mm
- **Camera Tilt:** down (level for an alternate shot)
- **Shot:** Long
- **Tripod Height:** 69.5 inches from bottom of camera (lower height for an alternate shot)
- **Settings in Camera:** 1/60, 100 ISO, 5100K, f 3.5 (f-stop may change in new camera position, use settings you figured out earlier today for this shot)
- **Camera Position:** Moves to “cam 4”
- **Movements:** Camera is stationary.

**Lights**
- Lights stay in same position and setting (see “lighting” setup page) until shot 10

**Talent**
Stays the same
6 – Dancer 1, 2 and 3 will go to next positions – Long Shot

Shot Description:
When each dancer is in the next positions they will begin to walk to their next individual positions. Dancer 1 will slowly walk backward. Dancer 2 will walk back towards the right. Dancer 3 will walk back toward the left. When they all get to their positions they will put down their baskets and stay down.

Shot Setting
Stays the same

Camera
- **Focal Length:** 35mm
- **Camera Tilt:** down (level for an alternate shot)
- **Shot:** Long
- **Tripod Height:** 69.5 inches from bottom of camera (lower height for an alternate shot)
- **Settings in Camera:** 1/60, 100 ISO, 5100K, f 3.5 (f-stop may change in new camera position, use settings you figured out earlier today for this shot)
- **Camera Position:** Stays at “cam 4”
- **Movements:** Camera is stationary

Lights
- Lights stay in same position and setting (see “lighting” setup page) until shot 10

Talent
Will walks to their next positions
7 – Dancer 1 will dance her individual dance - Full Shot

**Shot Description:**
Dancer 1 will dance to the rhythm with slow fluid movements

**Shot Setting**
Same as above

**Camera**
- **Focal Length:** 24mm
- **Camera Tilt:** Level
- **Shot:** Medium
- **Tripod Height:** 72 inches
- **Settings in Camera:** 1/60, 100 ISO, 5100K, f 3.5 (f-stop may change in new camera position, use settings you figured out earlier today for this shot)
- **Camera Position:** Move to “cam 7”
- **Movements:** Camera is stationary

**Lights**
- Lights stay in same position and setting (see “lighting” setup page) until shot 10

**Talent**
- Make natural slow movements (shuffling feet or shifting feet)
7 – Dancer 2 will dance her individual dance - Full Shot

**Shot Description:**
Dancer 1 will dance to the rhythm with slow fluid movements

**Shot Setting**
Same as above

**Camera**
- **Focal Length:** 24mm
- **Camera Tilt:** Level
- **Shot:** Medium
- **Tripod Height:** 72 inches
- **Settings in Camera:** 1/60, 100 ISO, 5100K, f 3.5 (f-stop may change in new camera position, use settings you figured out earlier today for this shot)
  - **Camera Position:** Move to “cam 7”
  - **Movements:** Camera is stationary

**Lights**
- Lights stay in same position and setting (see “lighting” setup page) until shot 10

**Talent**
- Make natural slow movements (shuffling feet or shifting feet)
7 – Dancer 3 will dance her individual dance - Full Shot

Shot Description:
Dancer 3 will dance to the rhythm with slow fluid movements

Shot Setting
Same as above
Camera
- **Focal Length:** 24mm
- **Camera Tilt:** Level
- **Shot:** Medium
- **Tripod Height:** 72 inches
- **Settings in Camera:** 1/60, 100 ISO, 5100K, f 3.5 (f-stop may change in new camera position, use settings you figured out earlier today for this shot)
- **Camera Position:** Move to “cam 7”
- **Movements:** Camera is stationary

Lights
- Lights stay in same position and setting (see “lighting” setup page) until shot 10

Talent
- Make natural slow movements (shuffling feet or shifting feet)
REFERENCES


Doloswala, K. N., Thompson, D., & Toner, P. (2011). Digital based media design: The innovative contribution of design graduates from vocational and higher education


