PERSPECTIVES FROM EDUCATORS REGARDING

THE INTEGRATION OF ART AND SCIENCE IN THE CLASSROOM

A Dissertation Presented to the
Faculty of the College of Education
University of Houston

In Partial Fulfillment
of the Requirements for the Degree

Doctor of Education

by

Melissa J. Lobpries

May 2016

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May 2016

Acknowledgment

I would like to acknowledge my loving, supportive husband, Trey Lobpries. I would not have made it through this grand feat without him. He is so patient and understanding, and saw me through the good, the bad, and the ugly. I would also like to acknowledge my family, Denis, Jo, and Vanessa, for always being there for me through thick and thin. I am very blessed to have so much love and support in my life.

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Lobpries, Melissa J. Perspectives from Educators Regarding the Integration of Art and Science in the Classroom. Unpublished Doctor of Education Dissertation, University of Houston, May 2016.

Abstract

Art and science have had a dynamic relationship over the centuries. With the progression of art and science through the course of human history, connections between the two fields are inevitable, as seen in the works of Leonardo da Vinci (late fifteenth-early sixteenth centuries) or Andy Goldsworthy (late twentieth century-present). Despite periods of misunderstanding and separation, art and science collaborations have occurred throughout history and modernity. This qualitative case study intends to highlight, through literature and research, these collaborations and the benefits for education. In addition, findings from this study will be generated to develop ideas for an emergent curriculum called Artistic and Scientific Knowledge (ASK), which is a collaboration of art and science teaching and learning in the classroom. The purpose of this study is to bring teachers' perspectives to the forefront, and to encourage art and science teachers to collaborate.

After further literature review, the rationale for an ethnographic research methodology and other related research is discussed. Using this methodology, a pilot study was previously conducted in which I investigated the perspectives of two art teachers regarding the idea of ASK teaching and learning. This dissertation study expands on my early pilot study and includes a group of three art teachers (two of them from the pilot study) and three science teachers. I continue using the ethnographic

research methodology, and conduct interviews with my participants. The interview questions involve the integration of art and science in the classroom, and aim to determine the feasibility of an ASK curriculum in the high school setting. Subsequent to the interviews, I analyze the data and include my own perspective, as an art teacher and researcher. Several themes that emerged from this analysis are: teachers felt 1) both art and science have concepts/aspects that are difficult to understand; 2) a curiosity and interest in learning more about certain aspects of each other's subjects; 3) commonalities between art and science are: creativity, discovery, problem solving, thought process, and use of visuals; 4) in favor of integration, with a need for guidance on how to do and apply it – logistical issues; 5) in favor of incorporating the other subject's concepts into their lessons, with a willingness to learn more; 6) students would benefit from learning art and science concepts together; 7) an ASK curriculum is feasible in the high school setting; and 8) in favor of collaborating with one another to further develop this type of curriculum. Drawing from these findings, I articulate ideas of the proposed ASK curriculum, as well as possible future collaborations with other art and science teachers.

This study is significant to teachers, administrators, and curriculum designers within all levels of art education and science education. More often than not, art education is seen as less necessary than core subjects, such as math and science, for student success in the real world. Through research, analysis, and interpretation of art and science collaborations, both in schools and in the real world, I discuss the positive implications that art has had on science teaching and learning and vice versa. Successful results of art and science education collaborations are encouraging to teachers,

administrators, and curriculum designers who are reinventing or redesigning curricula to fit twenty-first century thinkers.

Keywords: Artistic and Scientific Knowledge (ASK), interdisciplinary, integration, ethnography, art education, science education

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Chapter 1

The Dynamic Relationship of Art and Science

Introduction: Inevitable connections

As art and science have progressed throughout human history, connections have occurred as a matter of course. In the twentieth and twenty-first centuries, technology has sped along this course to connect art and science even further, to a point of possible mutual dependence. Herbert Weigand (1985) elaborates, "art and science, yin and yang, are two sides of the same coin; each depends on the other for its existence" (p. 18). Weigand's (1985) words about these two disciplines, about objectivity not being able to exist without subjectivity, reinforce my love of both art and science. I deeply value both disciplines for their inspiration of inquiry and understanding. Appreciating artworks requires asking questions about their content, context, function, and forms. Discovering the answers to these questions provides valuable information about artists, cultures, historical events, and, on a grander scale, how we interpret our place in nature. Science also seeks understanding of our place in nature through inquiry. The scientific method provides strategic steps of hypothesizing, experimenting, analyzing, and evaluating. The work of scientists builds upon those who came before them, for the greater goal of understanding ourselves, and the universe in which we reside. In addition, both art and science enhance inquiry and understanding through processes of creating, experimenting, and evaluating. Whether it is a paintbrush or a test tube, these two disciplines both have the tools with which we can put our ideas and questions into practice.

These methods of thinking and learning from both fields are vital for me to better appreciate the world and to facilitate my questions and curiosities. I am not the only one

who feels this way. For centuries, both artists and scientists have sought to understand the natural world (Friedman, 1997; Smith, 2009; Wenham, 1998). Weigand (1985) articulates the relationship between art and science:

> Although art and science are commonly regarded as polar opposites, philosophers, scientists, and artists recognize the interdependence of these two branches of knowledge. For these scholars, artistic and scientific modes of inquiry do not exclude, but enhance and balance each other. Each discipline investigates and makes manifest in a different form the duality of the human condition. (p. 18)

For quite some time, I have felt this love of both art and science, but I thought that I was restricted to one specialization. I am definitely an artist rather than a scientist – my science education stopped after sophomore year of college but my art education has continued, an experience that I cherish. However, that does not mean that I cannot continue to learn about science, nor that I cannot incorporate both disciplines into my teaching and learning. Many individuals have been both an artist and a scientist (Czor, 2007; Kemp, 2004; Kemp, 2011; Pepperell, 2011; Uffelman, 2007) and I draw inspiration from them. Doug Czor (1990) is a metal sculptor from Albuquerque, New Mexico. Before becoming a full-time artist in 1985, Czor (1990) believes that he fused his personal artistic and scientific ideas while employed as a geologist at the Massachusetts Institute of Technology (MIT). He began to create artworks that combine the creativity of art and science. Czor's artworks function as a bridge between art and science, as well as inquiry into global issues. For example, "One Wind," a sculpture composed of a stacked flagstone pyramid and topped with a painted steel circle with three whooping cranes, is a memorial to the cranes that no longer live in New Mexico (Czor, 2007). This

work “is also an inquiry, asking humanity to help wildlife survive, even as globalization and climate change continue to deepen around the world” (Czor, 2007). I am inspired by Czor’s artworks, which connect the creativity of art and science. Also motivating are his views that art can “stimulate interest in our young people for science and technology” (Czor, 2007). I share this view that bridging art and science can provide new stimuli for students in many aspects, especially creativity, inquiry, and global issues.

Another inspirational individual is chemistry professor Erich S. Uffelman (2007) of Washington and Lee University in Virginia. He teaches two interdisciplinary courses for science majors and nonmajors, in which they technically examine seventeenth century Dutch paintings. He reports that the classes are both strongly successful, and that the chemical education community has long recognized the value in technical examinations of artworks as a teaching tool in science education (Uffelman, 2007). Uffelman is a scientist who values the analysis and evaluation of artworks. Through technical examinations of the Dutch paintings, he finds creative ways to teach chemistry concepts. He has connected art and science in his classroom, with successful results. This type of teaching and learning inspires me for my own classroom, and can for those of my art and science colleagues.

Leonardo da Vinci as Inspiration: The Rebirth of the Artist-Scientist

Many artists, scientists, and educators feel that the modern collaborations of art and science are not surprising and are, in fact, necessary for the success of young people in our increasingly globalized society (Czor, 1990; Frazzetto, 2004; Kemp, 2011). Czor (1990) foresees that in a time when worldwide issues threaten the earth, we will need

more creative engineers and scientists to maintain a healthy equilibrium. We will also need more artists able to reveal the human state of mind that is immersed in vast amounts of technology. I agree with his viewpoint, and I feel that the creative thinking of artists combined with the technical thinking of scientists proves to be a strong force against the multifaceted issues that our society faces. Frazzetto (2004) reiterates that the public looks to science for answers to practical problems for a better world, and to art to participate in personal visions of the experiences of life. Practicality without vision leaves one side of the coin unturned. The solutions of science, like those of technology, often leave out the human aspect denoted by art. Without the personal expression and creativity of art and design, we would live in a very stale objective world. Kemp (2011) believes that both art and science have standards in the formulation of hypotheses, gathering of evidence, and evaluation of sources. These commonalities strengthen the collaboration of the two fields. Kemp (2011) explains, "the notion of artists and scientists collaborating is no longer a surprise, and is a well recognized strategy in the art world" (p. 279). The increase in collaboration of the two disciplines is a part of the modern phase of art and science's relationship.

The waves of art and science's dynamic relationship have had peaks and troughs of notoriety for artist-scientists. During the days of Leonardo da Vinci (late fifteenth-early sixteenth centuries), he used art and science, as well as engineering, in unison to understand his world. After periods of separation for art and science occurring in the nineteenth century (Else, 2010; Kagan, 1994), the two fields have made their way back to each other in our post-industrialized, technology-driven society. Davis (1973) paints a picture of Leonardo's world for our modern understanding:

> Leonardo da Vinci lived in a different, less informing landscape. He was forced to actively seek new knowledge. He worked closely with the anatomist Marc Antonio della Torre to learn what he needed to complete his figure studies and drawings. . . . Living in a preindustrial society, before the triumph of specialization, he felt no hesitancy about assuming the engineer's as well as the artist's role. He planned and constructed field guns, flying machines, and kinetic theaters. It is not accidental that our time, which is post-industrial in nature, thanks to the computer, is witnessing a rebirth of the artist-engineer. (p. 16)

Da Vinci actively sought new knowledge. He asked questions about art, anatomy, hydraulics, mathematics, engineering, and nature (Bramly, 1988). He observed the world around him, and used artistic and scientific knowledge to explore and answer his questions. These inquiry processes of art and science are why I thought of an acronym for Artistic and Scientific Knowledge, or ASK. Kemp (2004) reiterates, "every act of looking and drawing was, for Leonardo, an act of analysis, and it was on the basis of these analyses that the human creator can remake the world" (p. 5). The ability to inquire and to analyze gives us the power to construct and reconstruct our ideas and understandings of the world. With da Vinci as my inspiration, I began to explore this idea of the collaboration of art and science beyond the mere integration of some art into a science project, or vice versa. I wondered about the combination of artistic and scientific knowledge into the teaching and learning of one classroom. If more collaborations are occurring between artists and scientists to understand the real world, then it makes sense that this should be happening in the classroom as well.

Interdisciplinary or Integration

Many scholars and educators have been exploring the collaboration of art and science in the classroom (e.g., Chessin and Zander, 2006; Mills, 2013; Uffelman, 2007; van der Veen, 2012; Wenham, 1998). This collaboration is often referred to as *interdisciplinary* or *integration*, terms that have become more prevalent in modern educational research and practice (e.g., Bopegedera, 2005; Moore, 2001; Yarker & Park, 2012). These terms seem to be used quite interchangeably, so I feel that some clarification is necessary.

Interdisciplinary education, according to Wilson (1995), can be defined as a connection-making education. As explored by Fogarty (1991), these can be connections between lessons, across several disciplines via themes, and/or within and across learners who relate personal experiences to course content (Ulbricht, 1998). Interdisciplinary relates to more than one branch of knowledge. According to Merriam-Webster (2015) interdisciplinary is defined as: "involving two or more academic, scientific, or artistic areas of knowledge: involving two or more disciplines" (http://www.merriam-webster.com/dictionary/interdisciplinary). Interdisciplinary education takes knowledge from two or more disciplines and makes connections with that knowledge. In the classroom, this is common under the use of a theme. For example, an interdisciplinary lesson involving art and science can be centered on the theme of color, in which art knowledge of color schemes and design is combined with science knowledge of light and the visible spectrum.

Integrated education, according to Vars (1991), is a fully fused approach in which one theme, topic, or problem is approached from many different disciplines (Ulbricht,

1998). Merriam-Webster (2015) defines the word integrate as: "to combine (two or more things) to form or create something; to make (something) a part of another larger thing" (http://www.merriam-webster.com/dictionary/integrate). Integrated education takes two or more disciplines and combines them together to form a new discipline or to address a certain content area. Many times this approach does not provide equality for the individual disciplines and one may even become buried by another. For example, art integration is combining art with another subject such as science or math. With this approach, art is used as a project-based support to enhance the science or math curriculum. The art curriculum gets lost under the science or math curriculum, and math or science is not equally used to support art content. While integrated art education can yield positive results for the other subject, the enhancement of the art curriculum is not prevalent. Also, while not as likely, the other subject's curriculum can get lost among the art curriculum. A goal of the ASK curriculum, however, will be equal support and enrichment of both art and science. As one can deter, the terms *interdisciplinary* and *integration* can be used interchangeably, which is the case in my research. Interdisciplinary, or integrated, education involves knowledge from two or more disciplines and can be centered on themes and connections. It fully combines separate content areas – such as art and science – into a new whole, which is what I envision for the ASK curriculum.

In Ulbricht's (1998) guidelines for interdisciplinary education, I found two to be quite relevant to my ideas of what art and science collaborations in education should be. First, that interdisciplinary teaching "should be done in such a way that *each* element is enhanced by the others and *new* understandings are developed as a result of the

connections" (Ulbricht, 1998, p. 16). The author even mentions Leonardo's sketchbook drawings as an inspiration for interdisciplinary teaching because the science, writing, and drawing are revered individually but their combination is stronger than the individual parts (Ulbricht, 1998). Second, that interdisciplinary art teaching should be organized around themes, which incorporate concepts from different disciplines. According to Ulbricht (1998), "Themes give form to isolated facts, serve to integrate discrete bits of knowledge, and develop frameworks that enable meaningful and purposeful learning" (p. 16). As an art teacher, I want my students to experience "meaningful and purposeful learning," and I believe many other teachers feel the same. An interdisciplinary curriculum, ASK, is proposed to provide this type of learning. To address this interdisciplinary standpoint, it is important to understand the disciplines of art and science as separate but equal entities.

The discipline of art has changed frequently since the 1960s, when it became an official discipline (Efland, 1988), but has centered on the content of the elements of art and the principles of design. The elements of art include: line, shape, form, space, texture, value, and color. The principles of design incorporate: repetition/pattern, emphasis, balance, contrast/variety, rhythm/movement, unity, and proportion. The design process is utilized in art for the production of artworks. This process follows the steps of: 1) Asking – what is the problem/theme and what are the guidelines; 2) Imagining – brainstorming ideas and choosing the best one; 3) Planning – drawing sketches and gathering needed materials; 4) Creating – following the plan and creating the artwork; 5) Evaluating – what was successful/unsuccessful and what changes to make, if any. The design process is woven into three of the four Texas Essential

Knowledge and Skills (TEKS) for Fine Arts. The four TEKS are: foundations-observation and perception, creative expression, historical and cultural relevance, and critical evaluation and response (http://www.cedfa.org/new-teks-2015/art-teks/level-i-art/). Historical and cultural relevance is the only TEK that lies outside of the design process, although it certainly has some influence upon artistic understandings and decisions. The elements and principles are addressed under foundations: observation and perception, the first listed TEK. The discipline of art is as much about process as it is about production, a trait shared with the discipline of science.

The science discipline has also undergone changes as far as content and approach (Adams and Fuchs, 1985), but has centered on the scientific method. The scientific method is comprised of the following steps: 1) Asking a question; 2) Conducting background research; 3) Constructing a hypothesis; 4) Testing with an experiment; 5) Analyzing data and drawing conclusions; 6) Communicating results. The scientific method is incorporated into the TEKS for science, specifically the first three. The first three TEKS are categorized as scientific processes, while the subsequent TEKS are scientific concepts (http://ritter.tea.state.tx.us/rules/tac/chapter112/ch112c.html). The number and description of concepts varies for each specific branch of science. While understanding the concepts of science is vital, putting those concepts into practice is equally as valuable. Using scientific knowledge to inquire, hypothesize, experiment, and evaluate provides new and ever-changing understandings of the world in which we live. Artistic knowledge and experience also presents these understandings.

The disciplines of art and science are similar in multiple ways. The design process and the scientific method encompass the same steps – beginning with inquiry. In

both art and science, questions are asked and ideas are explored; research is conducted and ideas are put into practice with experimentation; and results are analyzed and communicated to others. Also, art and science both thrive on classifications. Nature can have many aspects without organization, but scientists seek to organize it so that we can make sense of it. Art crosses many boundaries, but art historians strive to classify it into certain categories. Additionally, in their respective fields, artists and scientists build upon the work of those who came before them. Their work adds to the knowledge of the field, as well as to explorations of self, society, and nature. These similarities have brought artists and scientists together in collaboration – brainstorming ideas and experimenting to fulfill new curiosities. While the art and science disciplines possess these similarities, they also have their differences. Art is considered subjective, while science boasts objectivity. Art is about expression, while science seeks objective truth. The science TEKS identify very specific concepts for students to learn and the art TEKS rely on students improving perception, creativity, and the ability to make informed judgments. The judgments mentioned in the science TEKS require empirical evidence and logical reasoning for their evaluation. The disciplines of art and science possess more similarities than differences, however, which have led to more collaboration (Kemp, 2011). My research seeks to uncover the perspectives of teachers regarding these collaborations.

How Do Art and Science Teachers Really Feel?

Art and science curricula possess commonalities in content, such as light, color, and perspective, and in thinking processes such as the scientific method and the design

process. Elaborated upon in Chapter 2 are many studies that have been conducted by teachers, which report the positive benefits of art and science collaboration. Teachers are collaborating more and exploring methods and techniques that expand beyond the four walls of their classrooms (Hamner & Cross, 2013). As a high school art teacher, I began to wonder how my fellow art teachers feel about an integrated curriculum of art and science.

Existing literature regarding art and science teaching and learning seems to bear a gap where high school art teachers' perspectives are involved. Much of what I have found, while quite intriguing, either addresses courses that integrate art and science, conducted and interpreted by science teachers (e.g., Uffelman, 2007; van der Veen, 2012); or research conducted by art education professors that discuss the benefits of collaboration but do not provide detailed perspectives of the teachers involved (Chessin & Zander, 2006). Also, much of the literature addresses higher education experiences. If an emergent curriculum is proposed, I want to know how my fellow art teachers respond to it. If the teachers do not see the benefit, then they may not try to implement it. Perhaps many art teachers are incorporating science into their classrooms and they would benefit from a framework for ASK teaching and learning. This framework could outline ways to incorporate more science for those who are interested, and provide a checklist for scientific concepts that art teachers can review to strengthen art and science integration in their classrooms.

Research Question and Purpose of the Study

With these thoughts in mind, I decided to conduct a pilot study of two high school art teachers to discover new attitudes/perspectives towards ASK teaching and learning. I addressed the research question: What are art teachers' attitudes/perspectives towards ASK teaching and learning? For my dissertation study, which includes three art teachers and three science teachers, I have modified the research question: What are the perspectives of art teachers and science teachers regarding the integration of art and science in education? My research question changed after further consideration of clarity and logical sequence. I have ideas for the ASK curriculum, but have not fully developed it yet. In order to further elaborate ASK, which will aim to integrate art and science, I need to gain teachers' perspectives on art and science integration in general. This dissertation research will help me grasp the feasibility, stipulations, and structure of the proposed curriculum. I use an ethnographic qualitative approach, and this dissertation includes a justification for my use of ethnographic qualitative methods as opposed to other research methods. The purpose of this research is to bring teachers' perspectives to the forefront, to encourage art and science teachers to collaborate, and to gain insight into the development of the ASK curriculum. The dynamic relationship of art and science has evolved and strengthened over the centuries. Through this research, it is my hope to reveal the connections and/or hindrances to strengthening the partnership of art and science in education. The proceeding literature review highlights the history and current strength of this dynamic relationship of art and science.

Chapter 2

Literature Review

Introduction

In order to make progress toward a better future, we need to understand and learn from the past. Considering that the collaborations between art and science are central to this study, it is important to review the literature to understand the history of these partnerships and the current strength of art and science's dynamic relationship. Also, teachers' and researchers' perspectives add vitality to this study, so it is necessary to explore these viewpoints from published studies concerning art and science collaborations, which occur both in the real world and in the classroom. Perspectives presented here are from artists, scientists, and educators who have worked in the educational field and/or conducted their own interdisciplinary research – data which are important for insight into the educational benefits of art and science partnerships. The literature review will address both art and science collaborations and teachers'/researchers' perspectives; Chapter 3 will address the use and reasoning of an ethnographic approach for my own research.

History of Art and Science Collaborations

In the beginning of what is considered Western society, the Greeks and the Romans defined the arts in relation to product and technical skills. Kagan (1994) elaborates, "The Greek term *techne* includes both crafts and plastic arts, as does the Latin

term *ars*; the modern 'art' refers not only to 'artistic creation' but also to 'artistry' or high skill in any activity" (p. 409). For example, Leonardo da Vinci referred to painting as a science (Kagan, 1994). Not only in skill, but also in definition, the boundaries of art and science are blurred. Many skills or professions can be defined as either an art or a science, such as the art and science of teaching (Marzano, 2013). How can a skill be both an art and a science? Interestingly, Merriam-Webster (2015) defines science as "knowledge about or study of the natural world based on facts learned through experiments and observation" (http://www.merriam-webster.com/dictionary/science). The dictionary lists art as "skill acquired by experience, study, or observation" (Merriam-Webster, 2015, http://www.merriam-webster.com/dictionary/art). The common words in both of these definitions are study and observation. Art and science share the fertile ground into which the seeds of collaboration can be planted.

Have art and science always been viewed as similar to and influential upon one another? Smith (2009) posits that in the history of "early modern" (p. 364) science, artisans and practitioners were quite influential on the field. Smith (2009) discusses studies of artisans and practitioners from the era of "early modern" (p. 364) science (the years 1400-1750), which have made it clear that a central dimension of the history of science is the relationship between making objects and knowing nature. This relationship reiterates an inevitable connection between art and science: understanding nature combines study and observation with creative experimentation and practice. Metaphoric thinking has also been a characteristic of the art and science connection since the seventeenth century. This creative type of thinking was common to artisans and

practitioners and, when combined with scientific concepts, spurred new interpretations of the universe. Friedman (1997) explains:

> In the seventeenth century, Isaac Newton's cosmology combined with a tradition of clockworks and automata to create a new metaphor, the clockwork universe. For two centuries poets and artists joined scientists and philosophers in trying to explain what this idea meant in terms of the human condition. (p. 6)

Evident in the literature thus far is that, for quite some time, artists have had a place alongside scientists in seeking explanations of natural phenomena. Just because one is an artist by trade does not mean science is off-limits. Artistic and scientific perspectives and knowledge joined together are a powerful force for understanding and learning.

In terms of seeking knowledge, modern science has moved further from strict empirical research toward the more interpretive and perceptual thinking of the arts. Adams & Fuchs (1985) report, "science itself is making more use of the type of metaphoric thinking and perceptual skills commonly found in the visual arts and humanities" (p. 22). The authors mentioning of perception recalls the terms study and observation, from the definitions of both art and science. To fully perceive nature, it is necessary to not only study and observe, but also to open one's mind to different interpretations. Strict empirical thinking of the scientific mind, without openly perceptive artistic thinking, loses much data from the multifaceted system that is nature (Adams & Fuchs, 1985).

Just as nature is seen as a system of cooperating parts, this outlook can also translate to art and science. Instead of thinking of art and science as two unrelated, specialized disciplines, they should be viewed in terms of common ground and

collaboration. Wenham (1998) believes that the history of the two disciplines shows that there has always been common ground between them, when "both are considered as investigative and interpretative activities through which people experience, learn and communicate" (p. 64). Despite this collaborative view, however, artists and scientists have not always seen eye to eye, nor has society viewed art as equally valuable as science in terms of practicality and dependability.

The Split in the Relationship

When two partners in a relationship do not treat each other equally, a split often occurs. Eisner (2002) discusses the cultural dominance of science over the arts as stemming from the Enlightenment period (mid-seventeenth century through the eighteenth century) in Western society:

> Science was considered dependable; the artistic process was not. Science was cognitive; the arts were emotional. Science was teachable; the arts required talent. Science was testable; the arts were matters of preference. Science was useful; the arts were ornamental. It was clear to many then, as it is to many today, which side of the coin mattered. (p. 6)

In this view, the art-science coin is much different from Weigand's (1985) yin and yang view of the coin. Even though art and science developed together in Western society, a separation of the two fields did occur. While Eisner (2002) links this split to the Enlightenment period, Kagan (1994) refers to the segregation of art within culture as occurring in the nineteenth century. He defines art as an "aesthetic phenomenon," (p. 409) which is concerned with the appreciation of beauty as opposed to human activities

like science, which "are dictated by practical needs, objective reality and natural laws" (Kagan, 1994, p. 409). In this view, the two disciplines are separated by the cultural view of aesthetics opposed with practicality. Modern design has shown us that these two functions can indeed exist together. Furniture and automotive design are two areas that highly utilize both aesthetics and practicality. Compared to the available methods of the nineteenth century, we have progressed greatly with the advent of technology, specifically the invention of the computer and ever advancing design software.

Even without advanced technology, however, art and science were embraced by many of the same people. Martin Kemp (Else, 2010) states that during the time of Galileo:

> Artists and scientists inhabited adjacent territories within a continuous landscape of visual activities. Galileo was a terrific draughtsman and a member of Florence's art academy. By the 19th century, however, a desperate desire to define art, design, engineering and the sciences as separate professional entities had set in. (p. 44)

The separation occurred around the subjectivity and objectivity of the two disciplines. Wenham (1998) suggests that the objectivity of science is comparable but not superior to that of the arts, and the separation of the "two cultures" (p. 61) is based on ideology and not reason. This ideology is the belief that knowledge in the arts is based on subjective responses, and that of the sciences on established objective truth. Wenham (1998) argues that newer ideas about the nature of scientific knowledge are, rather than being consciously proven, that the knowledge is more like "a report on progress so far, which future investigators will accept, modify or contradict" (p. 63). These newer ideas fit with

the collaborative aspects of both the art and science disciplines. The work of both artists and scientists builds upon the work of their predecessors. To understand nature and ourselves is to put together pieces of a puzzle. We either accept when the pieces fit, modify when they do not, or contradict the entire puzzle with new ideas and concepts.

Furthering the split in the art-science relationship was the increased specialization of disciplines in post-industrial society. Ulbricht (1998) posits, "historically, art developed in concert with evolving scientific discoveries and social concerns. After World War II, as the disciplines of knowledge became increasingly specialized, modern art seemed to distance itself from previous art styles and common everyday problems" (p. 14). As previously mentioned, during the times of Galileo and Isaac Newton, artists and scientists shared the same visual ground and the same discoveries. With advancing technology came increased knowledge that allowed for more specialized disciplines to handle that knowledge. Modern artists felt like they could explore specified areas that did not pertain to previous styles of art. These areas included the expressive use of color, non-traditional materials such as newspaper and cardboard, and new techniques such as photography. The sciences handled everyday problems and came up with practical solutions. Therefore, art during this time was explored and created for its own sake and identity.

This increasing specialization of the branches of knowledge, as well as a need for identity, led to art becoming a discipline in the mid-twentieth century. Efland (1988), in his explanation of how art became a discipline in the 1960s, discusses Phenix's (1964) more expansive view of the art and science fields:

A science . . . has a logical structure made up of facts, hypotheses, principles,

> generalizations, laws, and theories which provide explanations of nature . . . and its methods are observation and experiment. An art, by contrast, has a logical structure that emphasizes the individuality of the work of art as a sensible object. In place of the generalizations of science are the aesthetic intuitions of artist and viewer. The methods artists use involve imaginative cognition. (p. 268-269)

While it is true that artists foster imaginative thinking and aesthetics, we also create art from observation and experimentation. In addition, who is to say that scientists cannot involve creative cognition in their methods and explanations? The commonalities of art and science deny the structured categorizations put forth by Phenix. This compartmentalized treatment of the disciplines in education is exactly what many scholars and educators disagree with. Wenham (1998) reports, "compartmentalized teaching and learning means, however, that at present most students do not experience observation in art and science as the same ability being developed and used in the context of rather different but related enquiries and learning" (p. 67). Classrooms are physically separate containers of subject area contents, but teachers can bridge this separation by combining related knowledge and learning. In order for students to embrace complex real-world applications of the knowledge and skills they learn in school, an interdisciplinary approach is key.

Getting Back Together: Art Integration

In the twentieth century, art education began to explore integration with other disciplines. Art integration went through quite a few changes and, in the process, art almost lost its identity. According to Freyberger (1985), "as early as the 1920s,

correlation of art with other studies in the elementary curriculum was being explored" (p. 7). He explains that in the late 1930s and 1940s, art no longer functioned as a unique discipline but became integrated with all aspects of daily living (Freyberger, 1985). In the 1940s and 1950s, integration was a valuable part of progressive school programs. In the next two decades, art seemed to lose its identity as the subjects with which it was integrated received all the praise. Art educators fought for the very existence of separate programs of merit (Freyberger, 1985).

In relation to the ASK curriculum, I am not proposing for art or science to lose their identities, only for the thinking processes and knowledge of both disciplines to enhance one another. Freyberger (1985) agrees with an art program integrated with normal human experiences as a sound approach. In the 1980s, integrated art programs again became one of the trends; and Freyberger (1985) believes they will continue to be because "integration provides more meaningful experiences than can be achieved through separate study of narrowly defined subjects" (p. 8). What do contemporary teachers think? What do studies show? In the twentieth century, the gap has become narrower between art and science due to new uses for architecture, the rapid development of design and its importance in culture, and art based on new technologies such as photography, cinema, and television; and experiments in video art, kinetic art, and computer graphics (Kagan, 1994). Is the gap also narrowing between art and science in schools? Is society forcing art and science to confront one another? Some recent history studies and perspectives may shed light on these questions.

Prior Studies and Perspectives (1975-1995)

Philosopher and historian of science Thomas S. Kuhn (1977) emphasizes, "a confrontation between art and science is needed not only at the level of their products and activities, but also at the level of the public response" (Frazzetto, 2004, p. 235). Kuhn moves beyond purely process and product of art and science, and touches on society's reaction to this partnership. With the increased use of technology and its influence on the design process and the scientific method, the public is more accustomed to the mixture of science's practicality with art's aesthetics to solve logistical dilemmas. Frazzetto (2004) reiterates that the public looks to science for answers to practical problems for a better world, and to art to participate in personal visions of the experiences of life. The public, while desiring scientific solutions to practical problems, also demonstrates a need for an artistic outlet. This outlet, whether it is in the form of visual art, music, dance, or theatre, offers the public a way of understanding and participating in life's experiences. Practicality without creativity can hinder innovative ways of thinking. If there is an inevitable art-science partnership in society, then how will students react to the confrontation of art and science in the classroom? Will their attitudes toward these two subject areas improve? Weigand (1984) researched the answers to these questions.

In 1983, Weigand (1984) conducted a study to determine whether integrated art and science would improve the attitudes of secondary school students toward these two disciplines. The study consisted of integrated art assignments that focused on an aspect of nature in which an artist and a scientist would both be interested. The students completed ten weeks of art/science study, and were subsequently tested for their attitudes toward art and science, as well as their artistic and scientific knowledge retention. These

scores were then compared to an equivalent group of students who studied the standard studio course for ten weeks (Weigand, 1985). The author reports, "the comparisons revealed that the students who had studied art integrated with science had better attitudes toward both art and science and had better retention of science and art knowledge than did students who had not undergone integrated study" (Weigand, 1985, p. 21). Based on his 1983 study, Weigand (1985) believes that the "demonstrated mutual enhancement of art and science, when presented in a thoughtfully integrated context, furnishes the art educator with an additional argument in art advocacy and strengthens art's role in the general secondary school curriculum" (p. 21). I agree with Weigand that the mutual strengthening of art and science is key to a successful collaboration. Each discipline is utilized to enhance the other, which increases retention and understanding. Thoughtful collaborations with science teachers can provide art teachers with a way to expand art's role in the high school curriculum. Weigand's study is a strong example of broadening the thinking of both art and science, which is also occurring in the real world.

In comparing the real world and the classroom, Adams and Fuchs (1985) claim that "school-based art and science" (p. 23) have become victims of narrow thinking styles, which is occurring at the same time real world artists and scientists are broadening their questioning. The researchers explain, "a type of art and humanities instruction that nurtures creativity and deepens our understanding of the world will increasingly come into play as we move to understand our technology, ourselves, and the future" (Adams & Fuchs, 1985, p. 24). The art classroom should not be a bubble floating away from real world applications. Art instruction that incorporates science, technology, and social issues will better prepare students for the twenty-first century, globalized world. To

inspire this collaborative thinking in their students, art and science educators can look to artists who have incorporated science into their work.

Doug Czor (1990), a metal sculptor from Albuquerque, New Mexico, curated an exhibition called "Art and Science" (p. 225) in 1987. After observing grade school art teachers taking their students through the exhibition, Czor asked similar questions to those in my thoughts regarding art and science in education: "How can young people overcome their fears of science? What would happen if grade schools and high schools were to combine art classes with science classes?" (p. 225). He reported that students were elated with discovery and a sense of wonder when viewing the exhibition. They were more receptive to scientific explanations because of their enthusiasm for the artworks (Czor, 1990). The artist reflects, "I am not sure which came first in my childhood, the artist or the scientist. Perhaps they were born together and are inseparable, in spite of what is taught by many teachers and professors who assume that specialization is a necessity" (Czor, 1990, p. 226). This reflection is enlightening to me because Czor accepts that both disciplines are important in his life and evident in his work. He believes, as do I, that a person can be both an artist and a scientist. Before becoming a full-time artist in 1985, Czor (1990) feels that he fused his personal artistic and scientific ideas while employed as a geologist at the Massachusetts Institute of Technology (MIT). He began to create artworks that combine art and science. In his presentations to students, Czor (1990) leaves the message that it is good to be both a scientist and an artist. In a time when worldwide issues threaten the earth, we will need more creative engineers and scientists to maintain a healthy equilibrium. We will also need more artists able to reveal the human state of mind that is immersed in vast amounts of technology

(Czor, 1990). A healthy balance of art and science encourages an equally weighted scale of subjectivity and objectivity, of humanity and technology.

Technology also surfaces as being influential upon the relationship of art and science, especially because of the computer (Davis, 1973). The computer has revolutionized many aspects of our lives, and continues to do so. Graphic design, computer animation and filmmaking, medicine, and robotics are just some areas of art and science, which have changed immensely because of the computer. Due to its influence on art and science, technology is another avenue explored by researchers. The full range of technology in relation to art and science is beyond the scope of this paper, but a few examples are given for reference. Kagan (1994), for example, includes the influence of technology upon the history of the relationship between art and science:

> Thus, the history of the interrelationships between art, science and technology is characterized by the clash of two tendencies: their convergence to the point of complete integration and their divergence to the point of a complete alienation between "pure art" and "pure science." The dominance of one or the other of these tendencies depends on many factors, from the general level of cultural development to the individual psychological traits and the creative potential of a particular artist or scientist. (p. 409)

Kagan (1994) also refers to the waves in the relationship of art and science, which depend greatly upon cultural development. While this dependence on culture was more obvious to me, I had not considered the individual traits of artists and/or scientists as factors. As more artist-scientists, such as Doug Czor, spread their influence, the relationship of art and science grows stronger. One person can indeed broaden the thinking of many. In our

twenty-first century, technology-based society, individuals have strengthened the bond of art and science, as is evident in modern collaborations.

Recent Perspectives on Art and Science Collaborations

Our rapidly changing society brings the need to not only remember vast amounts of new information, but to access and apply it to challenges at hand. Needle et al. (2007) discuss twenty-first century learning and its facilitation by functional members of society who need to understand relationships between broad categories of information. These scholars explain, "this need for people with integrated knowledge has revitalized liberal arts education, which twenty years ago was seen as impractical when compared to preprofessional or professional programs such as law, engineering, business, or medicine" (Needle et al., 2007, p. 114). This impractical view of arts education fuels my passion to defend my field. If more non-arts students experience the value of art education, more judgmental barriers between disciplines will be torn down. Needle, an art professor, and Fulop, a biology professor, created a learning community for nonmajors in which science students could see the value of art in learning anatomy, while art students could see their discipline as a useful tool in understanding complex scientific knowledge. This community also introduced them to new fields such as medical or science illustration (Needle et al., 2007). Needle et al. (2007) comment that their learning community of art and science was successful beyond a specific discipline to the degree that it warranted publication. This idea of an art and science learning community is what I project the ASK curriculum as supporting. The sharing of knowledge and discipline

collaboration, and the opening of new doors for students are encouraging factors for an interdisciplinary approach.

Students' seeing the value in each other's respective disciplines is vital for a collaborative classroom experience. Both art and science use common methods of thinking and interpretation. Wenham (1998) argues, "students in both fields use concepts, theories, observations and arguments whose validity, along with the interpretations themselves, can be evaluated and debated by their respective communities" (p. 67). These concepts and theories stem from observing and evaluating nature and our place within it. Art and science students both question, interpret, and debate ideas and meanings in their respective fields. This common factor is encouraging for developing a collaborative curriculum. In fact, there are quite a few commonalities and correlations between art and science. Engler (1994) discusses that the origin of the tendency to compare art and science "can be attributed to the perception that both disciplines are associated with profound human experience and perception of the world" (p. 207). In art, we create artworks related to inner human nature, and in science, we systematically seek to create knowledge of the world (Engler, 1994). Engler (1994) believes that the common denominator between art and science is aesthetics – specifically the organization of structures – such as color, form, and space in art; and order, coherence, and unity in science. Aesthetics is the nature and appreciation of beauty, so both art and science have these organizing elements that appeal to an aesthetic admiration.

Frazzetto (2004) believes the common denominator between the two disciplines is the representation of nature. Frazzetto (2004) reflects upon the words of Miller (2000),

"art and science at their most fundamental are expeditions into the unknown, in which artists and scientists seek aesthetic representations of worlds beyond appearances" (p. 234). Art and science are both interpretative activities – both seek meaning and attempt to make the invisible visible (Frazzetto, 2004). Both Engler's and Frazzetto's concepts present more correlations between art and science. These disciplines serve to organize our ideas and allow us to explore new territory. Students can create new knowledge of the world by utilizing the similar methodologies of art and science. The design process and the scientific method are both ways of asking questions, experimenting, and analyzing. Large amounts of original thinking are necessary for each field to progress.

The design process and the scientific method are both cyclical procedures. Inquiry, experimentation, and analysis often lead to more inquiry and altered experiments. Original thinking spurs these activities and, in turn, the activities lead to more original thinking. On a broader scope, can science offer more ideas for artists and vice versa? If more artists like Doug Czor (1990) are incorporating science into their art, what may be the reason? The words of scientist Jean-Francois Brunet present an interesting idea, "science offers a new, virgin territory of contents, visions, spaces to occupy and explore with artistic means, a new frontier for art" (Frazzetto, 2004, p. 234). With the collaboration of art and science, members of both fields can benefit from new content and visions. To progress is to stray from the path of tradition. Art is a discipline that continually breaks with tradition and embraces contemporary connections. Ulbricht (1998) links postmodern art to more than just science: "Today, one can see in postmodern art strong interdisciplinary connections to personal, community, cultural, historical, and scientific events. Thus, the discipline of art is becoming more interdisciplinary" (p. 14).

Art has embraced scientific events and concepts, and science has opened itself to more artistic ways of thinking. Many recent studies have explored the new frontier of art and science collaboration.

Art and Science Integration: Recent Studies (1996-2014)

In reviewing the literature, I have found there to be more modern studies (1996-2014) than recent history studies (1975-1995) conducted regarding art and science integration. This supports the notion that the relationship between art and science has grown stronger and elicits more investigation than in the past. Wenham (1998) comments on the significant common ground between art and science, and makes the suggestion, drawing on his own practice in education, that art and science can be integrated in education through "development of observation and common curriculum content" (p. 61). He believes that there are many obvious common content areas that make it apparent to cross the conventional boundaries between art and science in education. For example, color theory in painting and the physics of color are closely related (Wenham, 1998). Another example I have contemplated is kiln firing in ceramics and the chemical reactions that occur when heat is introduced to clay artworks. In education, art and science collaborations will be seen as worthwhile if they increase opportunities for effective learning in both disciplines (Wenham, 1998). Teachers are already under a lot of pressure, so engaging in this integration is clearly difficult, but not impossible. Exploration can lead to successful progress in art and science.

There are many approaches and methodologies for integrating art and science. For example, Moore (2001) relates the communication achieved with art to the study and

teaching of science through the analysis of a piece of art glass. Moore's approach may not work for other teachers; however, if learning is occurring in both disciplines, it is more likely that teachers will be more open to new methodologies. Frazzetto (2004) reiterates, "despite a history of different attitudes and approaches, art and science are engaging more often in collaborations of mutual benefit" (p. 233). If this mutual benefit is occurring in the real world, then it should occur in the classroom as well. Frazzetto further explains, "interactions between practicing scientists and artists are, in fact, becoming more frequent, as is the depiction of scientific concepts or experimentation in works of art" (p. 233). Frazzetto (2004) mentions the work of artists such as Gabriele Seethaler, Julie Newdoll, and Ross Bleckner, whose works draw inspiration from science. Seethaler uses her background in molecular biology to explore identity; Newdoll, in her latest paintings, recollects electron microscopy images of sensory organs; and Bleckner's recent paintings examine patterns of cells (Frazzetto, 2004). These artists can serve as exemplars for art and science teachers in their efforts of collaboration. If students are shown real-world occurrences, these will strengthen the proposed ASK curriculum. The isolated art and science classrooms will become a mutually beneficial learning community. In addition, Frazzetto (2004) reflects that the gap between art and science appears to be growing narrower. There are initiatives such as the SciArt programme at the Wellcome Trust in London, UK, where art and science crossover projects are funded with an aim to "explore new modes of enquiry and to stimulate fresh thinking and debate in both disciplines through innovation and experimentation" (Frazzetto, 2004, p. 235). While the SciArt programme is a part of a global charitable foundation, there are other initiatives occurring within schools.

In an educational crossover project, Bopegedera (2005) describes his experience as a chemistry teacher in designing and teaching an interdisciplinary course titled "Light," in collaboration with a visual artist. Chessin and Zander (2006) researched the collaboration between a middle school art and a middle school science teacher on multiple lessons. Before working together it was easy for the science teacher to dismiss the arts as “a frill” (p. 44), but after the collaboration she realized that the arts gave her students a new perspective on the science content (Chessin and Zander, 2006). Chemistry professor Erich S. Uffelman (2007) of Washington and Lee University in Virginia teaches two interdisciplinary courses for science majors and nonmajors, in which they technically examine seventeenth century Dutch paintings. He reports that the classes are both strongly successful, and that the chemical education community has long recognized the value in technical examinations of artworks as a teaching tool in science education (Uffelman, 2007). These projects/studies, with their positive results, bring forth new ideas and encouragement for art and science connections and cooperation.

If science borrows from art, then art can borrow from science. Marshall (2006) states, “because current art focuses on content from all areas of life, it also calls for curriculum integration” (p. 18). The author also discusses constructivism, which had its origins in the early twentieth century with the theories of John Dewey (2001). Constructivism is partly based on the principle of learning as a connection-making process, in which the learner connects new experiences to prior ones to make sense of the new information. Marshall (2006) explains, “with its emphasis on conceptual connections, constructivism also suggests that learning in all subjects, art included, is facilitated and enhanced by integration with other subjects” (p. 18). The connection

making of constructivism harmonizes with art and science integration. Concepts from either discipline may connect more successfully with students' prior knowledge by integrating those concepts. For example, attempting to explain the definition of color as an element of art connects well with the scientific explanation of light and the visible spectrum. Most students have prior knowledge of rainbows, so I relate this knowledge to the art and science of color and light. In addition, Marshall (2005) makes valuable observations about integration, in that "it does not devalue art as a domain unto itself but acknowledges its power and scope" (Marshall, 2006, p. 19). She also reminds us that integration comes in many forms, from the superficial illustration of content from different subjects to the deeper exploration of the concepts these subjects have in common (Marshall, 2006). These different forms of integration are important to distinguish. A superficial approach, such as a science student drawing and coloring a plant cell, is not what I have in mind for the ASK curriculum. The deeper exploration of common art and science concepts – such as the use of the scientific method to analyze art works – for the mutual benefit of both disciplines, is the interdisciplinary approach I envision.

In regard to deeper exploration, Kemp (2009) discusses the budding field of neuroaesthetics, in which neuroscientists look at the psychological complexities of how we view and value pieces of art. Another initiative is the SymbioticA research centre at the University of Western Australia, Perth, which was inaugurated by two artists. It is a laboratory staffed by artists (Kemp, 2011). In the United States, there is the Art|Sci Center + Lab at the University of California, Los Angeles (artsci.ucla.edu). Kemp (2011) notes that these initiatives arose from concerns among artists and scientists that "the

divorce between their disciplines was unhealthy" (p. 278). These collaborative measures also display the strength of the art-science relationship. If artists and scientists are working together to preserve and fortify this partnership, then art and science educators can as well. Even so, how do teachers and students perceive this practice? Additional educational studies have addressed this question.

Another study, conducted by Heywood, Parker, and Jolley (2012), addresses the attitudes of pre-service teachers toward art and science integration in the United Kingdom. These researchers explore how the pre-service teachers' conceptualizations of these practices are mediated and influenced by their experiences in school (Heywood, Parker, & Jolley, 2012). This school experience also shapes students' perceptions of art and science. If they participate in an interdisciplinary curriculum, students will possess a deeper appreciation of the world through an artistic and scientific lens. Jatila van der Veen (2012), as a visiting researcher in the Department of Physics and lecturer in the College of Creative Studies at UC, Santa Barbara, focused her research on the application of drawing to the introductory college physics curriculum. The author taught a course called Symmetry and Aesthetics in Contemporary Physics, based on Greene's (2001) pedagogical model of Aesthetics Education. The arts-based learning strategies she used helped break down physics language barriers for both arts-oriented and minority culture students. One art major told van der Veen (2012) that after taking the course, her perception of her existence and of the world was opened up. The author's goal was to improve students' attitudes toward physics, which was achieved through visualizing abstract concepts (van der Veen, 2012). Van der Veen (2012) reports that, after teaching the class for four years, arts and humanities students have a greater appreciation for

physics and math, while physics students have a greater appreciation for the arts and the rigor involved in making art. Van der Veen took the deeper explorative approach to art and science collaboration. As a result, students from each discipline experienced the worth of the other, as well as an expanded perception of self and the world.

Art and science collaborations can provide additional ways for students to expand perceptions of their place in the world, by addressing environmental issues. Mills (2013) conducted a study at an urban high school of eight students in an advanced placement art class. The students were asked to research, develop, and create a unique piece of art for the school garden planted by the science teacher. The project took six weeks to complete and Mills (2013) reports successful results: "They saw the link between science and art and they moved from being competitive to being cooperative. The students became engaged with the environment as well as incorporating elements of the environment in their artwork" (Abstract). Mills (2013) includes a need for further research into art and science integration in high school:

> Further research is needed to determine if students in high school art classes could link the environment, science, and art to build a more comprehensive, inclusive, and cross curricular learning experience by completing similar projects to enhance their schools environment and develop an understanding of the interconnectedness between education and its practical applications. (Abstract)

I hope to fulfill some of this further research with my own qualitative study involving the ASK curriculum. Another area of research increasingly explored regarding art integration is STEAM. The integration of art into science, technology, engineering, and

math (STEM) fields, known as STEAM (Hamner & Cross, 2013), is an emergent methodology gaining strong support in education.

Hamner and Cross (2013) discuss a craft-based robotics program implemented in schools to support STEAM curricula. There are many initiatives to underpin STEAM; however, for my study, I am focusing on art and science rather than the full STEAM curricula.

The studies discussed so far have been examples from the United States and the United Kingdom, but there is also research being conducted in Arabic countries regarding art and science integration. The most recent study I have reviewed took place in the country of Oman. Al-Amri and Al-Yahyai (2014) examined "pre- and in-service art teachers' knowledge about arts integration within science and their attitudes toward teaching by an integrated method in the classroom" (Abstract). These researchers believe that "such an examination is especially important to art education faculty, as well as to school administrators and supervisors in the field as they continue to reconfigure traditional conceptual knowledge and formulate new pedagogies of teaching and delivering knowledge" (Abstract). I agree with the researchers, and I believe that high school should also be examined because many students are formulating their college plans in high school. The knowledge and skills they learn and discover in high school influence their college choices and career decisions. Therefore, it is necessary to examine how both art and science teachers and students feel about an interdisciplinary approach. Accordingly, the next section looks further in educator/researcher perspectives of art and science studies.

Recent Studies (1996-2014): Educator/Researcher Perspectives

Alan Friedman (1997) is a science educator who feels that art and science education need each other. In his research, he discusses a photograph of the Hercules Cluster of Galaxies from 1973, and his fascination with it and what we have come to know about the universe so far with the aid of this artistic medium. When reading his words, I feel the passion he expresses for science as well as his excitement for increased knowledge of the universe. Friedman (1997) mentions that children do not share this same fascination and passion for science. In reflecting upon what is wrong with science education in the United States, Friedman (1997) states, "I have concluded that the solution is not just finding more good science teachers and developing good science curricula, but also encouraging more and better arts education" (p. 3). Friedman (1997) believes that the arts can create a desire to learn – the passion and awe that is missing from science education. The author explains, "science can help us know what is there; poetry and the arts can help us know what is important" (Friedman, 1997, p. 5). He adds, "art isn't replacing science, nor science art, but each can help us comprehend the powers and limitations of the other" (Friedman, 1997, p. 5). This perspective mirrors my own, and is one that I hope to hear from more art and science teachers alike. The creative thinking processes of the arts can revitalize the sciences. Difficult, abstract, scientific concepts are often made clear through visual representation and interpretation, such as Friedman's photograph as a glimpse into galaxy formation. Friedman's view provides a positive outlook for the collaboration of art and science in the classroom.

Another positive, yet somewhat challenging perspective comes from

Wenham (1998), who states that his own teaching experience and practice show that it is possible to integrate art and science in education, and that it can be very rewarding when successful. The author does not elaborate any further on his practice or his perspective of art and science education collaboration. He only asks the question: " . . . does anyone have the will and motivation to overcome prejudices and habitual ways of thinking sufficiently to work in it [the common ground of art and science]?" (Wenham, 1998, p. 68). He poses a taxing question, but I feel that many teachers are capable of overcoming obstacles such as these. Teachers are constantly adapting to new policies and situations, as well as changes to their curricula.

Some researchers advocate for these changes as being motivation for students and ways of providing meaningful learning experiences. Krug and Cohen-Evron (2000) believe that as visual arts programs are moving from the margins to the core of school curricula (Wilson, 1997), the ways that art teachers "conceptualize and organize curricular knowledge will need to change along with their art teaching practices" (p. 258). The challenging processes of integrating curricula "can be supported through ongoing dialogue and collaboration among teachers from different disciplines with different perspectives as they discuss the importance of knowledge and issues that affect their everyday lives" (Krug & Cohen-Evron, 2000, p. 258). The ongoing dialogue between art and science teachers is crucial to implementing the ASK curriculum. If there is little communication occurring, collaboration will surely fail. Krug and Cohen-Evron (2000) have studied different art teacher practices and have discovered "an ebb and flow, an acceptance, rejection, and/or modification of certain characteristics" of what disciplinary ideas should be at the center of an art curriculum (p. 265). From their

research, Krug and Cohen-Evron (2000) discuss four art education curricular practices: "using the arts as resources for other disciplines; enlarging organizing centers through the arts; interpreting subjects, ideas, or themes through the arts; and understanding life-centered issues through meaningful educational experiences" (p. 258). Under the first practice, the authors mention a high school science teacher using art as a resource for teaching about the sun, but they do not elaborate on the teacher's perspective. While all of the practices seem to yield successful results for students and teachers, the authors do not include perspectives of these participants. Krug and Cohen-Evron's (2000) research "suggests the potential of integrated curricular practices as a way to provide students with meaningful learning experiences" (p. 271). I intend to investigate further and discover both students' and teachers' perspectives of, specifically, art and science integration.

Another scholar who calls for change is Marshall (2006). She believes that it is time for new models and ideas for art education, namely "an art education that is better connected to the concepts and ideas behind art and art practice, and to areas of inquiry outside of art" (Marshall, 2006, p. 17). In her research, Marshall (2006) describes an art integration project that was designed for upper elementary and middle school. This project explored "fundamental concepts from art, science, mythology, and popular visual culture" (Marshall, 2006, p. 19). In one part of the project, the author comments, "students come to view scientific illustration as a way of researching a subject through observation and interpretation" (Marshall, 2006, p. 20). While this result is the type that stimulates the art and science partnership, Marshall (2006) does not explore teacher perspectives in this research. In a different middle school setting, Chessin and Zander (2006) researched an art and science collaboration, and gave some idea of the teachers'

perspectives. The professors mention some great points that, I believe, high school teachers will also consider when thinking about subject integration:

> Today, issues of accountability, time, and the number of things that need to be taught in schools seem to be key ideas that govern learning in many classrooms. However, if we were to ask teachers the ultimate goal or achievement for all schooling, they would most likely answer that students should see learning as important and relevant to their lives. They might also express a desire that students be able to approach new ideas with a sense of open-minded inquiry and curiosity – things that lead to a lifelong love of learning. (Chessin & Zander, 2006, p. 46)

Open-minded inquiry and curiosity are qualities that the ASK curriculum can instill. Teachers can encourage each other to attempt new methods for the benefit of their students. Needle et al. (2007), for example, hope that by sharing their interdisciplinary teaching experience, they will encourage other undergraduate educators to use similar effective teaching methods.

Inspiration also flows from an art historian's point-of-view. As emeritus professor of Art History at Oxford, Martin Kemp (2009) focuses on his field: "Art historians and scientists need to work together to define new questions that are both tractable and of genuinely shared interest" (p. 883). Kemp (2009) believes that studying the arts is not a science, but the field has standards in the formulation of hypotheses, gathering of evidence, and evaluation of sources. He explains, "as an art historian, I dislike one hypothesis sitting on the shoulders of another unproven one as much as any scientist" (Kemp, 2009, p. 882). Gathering evidence and evaluating sources is a vital part

of art history. For my art history classes, I gather evidence regarding artworks, and my students and I evaluate those sources. We analyze and interpret the artworks, and form new hypotheses as more evidence is presented. The scientific method also utilizes similar steps, as discussed by Kemp (2009). As far as how artists can benefit from art and science collaborations, Kemp (Else, 2010) believes it is good "for artists to see that while appearing as a dry set of objectivities, science is deeply imaginative, social, partial and extraordinary" (p. 45). Kemp (2011) comments on the progress of art and science collaborations in education and in the art world:

> Educational initiatives are arising, ranging from school programmes to master of arts degrees, such as the two-year postgraduate course at the University of the Arts in London. The notion of artists and scientists collaborating is no longer a surprise, and is a well recognized strategy in the art world. (p. 279)

If the collaboration of artists and scientists is a frequent and unsurprising occurrence in the art world, then surely skepticism for its success in the classroom will diminish. The results can be enlightening and rewarding, as discussed by Pepperell (2011).

Artist and professor Robert Pepperell (2011) concludes that, from his artistic perspective, the investigations that he has undertaken with neuroscientists and psychophysicists have proved "illuminating and rewarding" (p. 11). He reflects, "I have become aware of the great potential of the scientific method to elucidate processes that artists often work with intuitively but rarely grasp in any systematic way" (Pepperell, 2011, p. 11). Pepperell (2011) also comments on the flip side of the collaboration coin:

> But I have also seen at first hand the limitations of the scientific method when

> studying the experience of art, and have been reminded of the very different cultures that exist between art and science that make meaningful collaboration a sometimes demanding process. (p. 11)

This is a significant perspective to consider. Despite their multiple commonalities, art and science still have individual distinctions. Each discipline is valuable in its own right, and it is crucial that the strengths of each field support rather than dominate the other. Pepperell (2011) reiterates, "art-science collaborations work best when each discipline is enriched through the process, rather than one being parasitic on the other" (p. 12). Although this is definitely a challenge, Pepperell (2011) believes that by honoring the distinct traditions of each discipline, without sacrificing the integrity of either, we can create "a truly interdisciplinary approach to the study of problems as complex as the way we make and appreciate art" (p. 12).

Another perspective regarding art and science collaborations in education, from van der Veen (2012), states:

> Although most of the research on the use of drawing for understanding has focused on primary education, I suggest that the use of drawing for understanding is entirely appropriate for introductory college students, who may harbor completely na¨ive interpretations of concepts in physics based on prior assumptions, misunderstanding of texts, or simply a lack of previous exposure to physics. (p. 365)

The author discusses the above-referred research from both primary and college education, but none from secondary. So I ask, what about high school? As a new high school teacher, the perspectives of these teachers are valuable to me. How do art and

science teachers feel about their respective disciplines working together? These questions guided me to my research study, in which I used an ethnographic qualitative approach to examine the perspectives of three high school art teachers and three high school science teachers. This endeavor led me to assess the feasibility and potential structure of the proposed Artistic and Scientific Knowledge curriculum.

Chapter 3

Methodology and Analysis

"Every act of looking and drawing was, for Leonardo, an act of analysis, and it was on the basis of these analyses that the human creator can remake the world" (Kemp, 2004, p. 5).

Ethnography and Education: Limitations and Benefits

Ethnography is a research methodology that began with anthropology and made its way over to education, with the help of anthropologists such as George Spindler (1955). Like any other mode of inquiry, ethnography is not without its own problems and limitations. The majority of ethnographies have been forms of descriptive research, capable of generating hypotheses but struggling to assess them. Overholt (1980) explains, "Many proponents of ethnographic field methods note that its strength lies in its capacity to generate relevant hypotheses, much less in its capacity to assess or verify them" (p. 13). He also refers to this weakness belonging to the "old, or classical ethnography" (p. 13) and that the "new ethnography" (p. 13) attempts to offer more explanatory power (Overholt, 1980). In my research, I aim to preserve the depth of description of classical ethnography and weave this with my own and my readers' interpretations and explanations.

Overholt (1980) discusses the view that most educational researchers are concerned with doing something "scientifically rigorous" (p. 15) and that ethnographic field methods have perhaps been criticized for being "unscientific" more than other modes of educational inquiry. These criticisms often focus on the areas of validity and reliability. The term validity refers to "the degree to which scientific observations record and/or measure what they purport to record and/or measure" (Overholt, 1980). The author states, "About the only control for validity developed by ethnography is the long-term stay in the field, combined with achieving as deep a level of participation in the community as possible" (p. 18). As a participant-researcher and art teacher in the research setting, I have a long-term stay in the field and am deeply involved in the community of my school, to help control for validity in my research. Overholt (1980) points out, "The typical school ethnography, for example, is conducted by one who is an outside observer and interviewer, but often not, to any great extent, a participant" (p. 18). I am not an outside observer and interviewer; and I am a participant because my aim is not only to encourage art and science collaborations, but also to participate in these myself.

The term reliability refers to "the repeatability of scientific research processes and their related findings" (Overholt, 1980, p. 18). The author refers specifically to ethnography's weakness in fostering replicability, which is where another investigator can repeat and independently verify, or refute, the results (Overholt, 1980). My research study aims to highlight teachers' perspectives and encourage art and science teacher collaborations, with the end result being the possible implementation of a proposed curriculum. I will present my findings with clarity and great detail so that they may assist

other researchers with engagement in similar processes. However, my intention is not to test a hypothesis at this point, rather to shed light on art and science classrooms, art and science teachers, and potential collaborations of both. This intention is why ethnography is the best approach for my research, a defense highlighted by Overholt.

Overholt (1980) mentions two responses that can be made in the defense of ethnographic methods for the study of education. First, that problems with validity and reliability are not unique to ethnography. Most modes of educational inquiry have similar issues to control for. Second, that for certain kinds of research questions, ethnography is the best approach. Overholt (1980) states,

> The reality of education lies in the meanings which emerge in the interaction between teacher and student, student and peer. . . .For those who wish to know what these meanings are and how to find a way to account for them, ethnography is the best tool currently available. (p. 19)

Another researcher who agrees with Overholt on the benefits of ethnography for education is Zaharlick (1992). She discusses, "Ethnography, with its inherent sensitivity to people, culture, and context, offers one approach to providing valuable new insights that can contribute to educational improvement and reform" (Zaharlick, 1992, p. 122). As a participant-researcher, I must consider the context of the school in which my study is taking place. If I do not understand the people (teachers and students) as well as the environment where I am attempting to encourage collaborations, then I risk achieving long-term success with a new curriculum. If those who may be implementing these ideas in their classrooms are not on board, and if I do not take their perspectives into account, then I will lose the validity and reliability that I am aiming to control for. Zaharlick

(1992) elaborates, “Approaches to improving instruction, curriculum, evaluation, or any other aspect of the educational process that do not take into consideration the surrounding context are at a decided disadvantage in achieving long-term success” (p. 122).

Theoretical Framework: Ethnographic Qualitative Approach

According to Stokrocki (1991), qualitative research is “a way of observing, interpreting, and analyzing an everyday experience in an attempt at understanding participants’ ideas and beliefs about it” (p. 42). In discussing qualitative research, Stokrocki (1991) mentions the need for researchers to listen more to what teachers and students are thinking about instruction (Nadaner, 1983) because there are big differences between theory and practice. As stated by Murchison (2010), ethnography is “a research strategy that allows researchers to explore and examine the cultures and societies that are a fundamental part of the human experience” (p. 4). The ethnographer as a researcher is not a detached observer, as in many other forms of scientific research, but gains insight through firsthand involvement with research participants (Murchison, 2010). There is an interaction between researcher and participant in ethnographic qualitative research that cannot be obtained through quantitative methods. Murchison (2010) further explains, “from the standpoint of ethnography, the only plausible way to study social and cultural phenomena is to study them *in* action” (p. 4). In my study, to gain insights into the perspectives and attitudes of art teachers and science teachers, I need to observe their teaching, interview them, and have conversations with them. Numbers cannot describe human emotion and experience, but ethnography can by turning those observations and conversations into written descriptions.

Murchison (2010) also comments that, “ethnographers seek to determine the extent to which individuals and groups share common behavior and thought” (p. 10). The result of this exploration is an ethnography that is more attentive to internal commonalities/disputes of a group, as well as different perspectives (Murchison, 2010). My study seeks different perspectives of art teachers and science teachers, and aims to discover common behaviors and thoughts regarding ASK teaching and learning. I want to be more attentive to their perspectives because they are the people engaged in the educational environment on a daily basis – their views are at the heart of teaching and learning.

Surveys and questionnaires can provide helpful information to the researcher, but many times these methods ask questions and use categories that originate from the cultural understandings or assumptions of the surveyors themselves. Murchison explains, “ethnography allows the researcher to discover and analyze the categories and questions that are most relevant for the people being studied and participating in the research” (p. 12). Being an art teacher myself, I am fully engaged in this research study – in terms of relevance to my field. Ethnography is appropriate for my research because surveys/ questionnaires that I may use still come from me and are biased by me. I am in favor of ASK teaching and learning, but my colleagues may not feel this way. Ethnography allows me to observe and interact with other art teachers’ and science teachers’ classrooms, to discover the types of questions/categories that are most relevant for them. Also, I can gain a unique understanding of how the classroom context informs art teacher and science teacher behavior by examining the teachers’ responses to an ideal situation compared with the real classroom situation.

Last, from Murchison (2010), I relate to the ethnographer's role as a student and the participant's (or informant's) role as a teacher. Murchison says that in order to be an effective researcher, one needs to be placed in a position to learn from others (2010). I agree with this statement, and this is what I am trying to do in my research study. My participants – the art teachers and the science teachers – play an important role in shaping and guiding the research process. Just as the high school students learn from these teachers, I am learning from their experience in the art and science classrooms, with public schools, and with the demands and politics of the educational system. I see my participants as associates in my research, and this is a role that ethnography honors more than other research methods. With ethnographic qualitative research, I can have a unique relationship with my research participants – one that I would not be able to have if I used survey or statistical methods.

According to Fetterman (2010), "verbatim quotations are extremely useful in presenting a credible report of the research" (p. 11). Quotations allow the reader to make their own judgments about the work, and to know how close the ethnographer is to the thoughts of the people whom they observe in the field (Fetterman, 2010). My research study includes verbatim quotations from art teachers and science teachers, as well as my interpretations of those quotations. The purpose is to present readers with my point-of-view as art teacher-ethnographer, and to allow them to make their own judgments about the words of the other art teachers and science teachers. If I included my interpretations without the original words of my research participants, I would hinder the ability of my readers to make their own judgments regarding the findings. This is another reason why

ethnographic qualitative research provides more insight into insider's perspectives – it allows for multiple interpretations of the data without the limitations of quantification.

From Spindler's (2000) criteria for a good ethnography, quite a few criteria support the rationale for this methodology for my research. First, (criterion II) hypotheses emerge in situ, or on site, as the study goes on in the setting selected for observation. Judgment on what may be significant to study in depth is deferred until the beginning phase of the field study has been completed. For my pilot study, I first spent time in the two art teachers' classrooms, observing and recording. This fieldwork gave me a chance to develop questions based on my observations, and to decide what was significant for my study. Next, (criterion III) observation is prolonged and repetitive. Chains of events are observed more than once to establish the reliability of observations. This criterion is crucial for my study since I am interested in art teachers' and science teachers' perspectives towards ASK teaching and learning. Their attitudes/perspectives may change according to many factors, so it is important that I observe chains of events to establish reliability. Change occurs frequently in education, so it is important to distinguish reliable observations. Then, (criterion IV) the native view of reality is attended through inferences from observations and through the various forms of ethnographic inquiry.

Criterion VI says that instruments, codes, schedules, questionnaires, agendas for interviews, and so forth, should also be generated in situ as a result of observation and inquiry. A trans-cultural, comparative perspective is present, though frequently as an unstated assumption (criterion VII). In my research, I want to point out this comparative perspective – art and science teacher perspectives. Also, a significant task of

ethnography is to make what is implicit, explicit to informants (criterion VIII). I found, through my interviews with the art teachers, that when asked more in-depth questions about their views, the teachers opened up more and became aware of their perspectives on science in art teaching. I believe this ethnographic approach brought the implicit dormant thoughts to the explicit surface and planted a seed for further thought in at least one of the teachers. I say this because she began to talk to me more about art plus science in our informal conversations during lunchtime.

Last, criterion IX states that interviews must be carried out to promote the unfolding of emic cultural knowledge in its most naturalistic form (Spindler, 2000). Fetterman (2010) also mentions the emic perspective – the insider's perspective of reality – as being at the heart of ethnographic research: "The insider's perception of reality is instrumental to understanding and accurately describing situations and behaviors" (p. 20). Educational reformers should look at the insider's, or teacher's perspective, concerning decisions that will affect those teachers. Administrators and policy makers who have not even taught in a classroom make crucial decisions, without regard to the emic view of teachers who can provide firsthand knowledge of the successful implementation of those decisions. My research presents the insider's (art teacher's and science teacher's) perspective of reality, and this in-depth approach is most suited in ethnographic research.

In their research, Kincheloe and McLaren (2002) mention the importance of the often-neglected domain of the interpretation of information. The interpretative aspect of qualitative research is the most important – the moment(s) of interpretation. For my research paradigm, the interpretive approach seems to be the best fit and the ethnographic qualitative approach provides the means for many moments of interpretation. Observing

the dynamics of the art (and eventually science) classrooms over time allows my interpretations of the research. Verbatim quotations from interviews provide for more interpretations by the reader and myself. The fieldwork involved in ethnographic research captures more moment(s) of interpretation than many quantitative methods.

Zou and Trueba (2002) explain, "qualitative research and critical ethnography in particular creates an opportunity for academicians and common people alike to put forth the stories of people, cultures, and communities" (p. 283). This is crucial to my research because I want to put forth the stories/perspectives of the art teachers and science teachers in such a way that any person will be able to interpret them. Readers can provide an additional interpretation of the stories of research participants. Ethnography supports that critical and interpretive approach to the ever-dynamic perspectives of teachers.

The Pilot Study

Procedures of inquiry.

As previously mentioned, a gap in the literature exists with the lack of art teachers' perspectives about the incorporation of science into their classrooms. Therefore, the pilot study was an effort to fill that gap by looking at the perspectives of two art teachers, regarding ASK teaching and learning. The pilot study is part of the dissertation study in that it provided greater insight of the inner workings of art classrooms through observations. The data from the pilot study served as groundwork for the expansion of art teacher perspectives in the dissertation study. These data allowed me to modify the research question and procedures of the dissertation study, for clarification

and improvement. In furthering the study, I interviewed three art teachers (including the two from the pilot study) as well as three science teachers. Gaining current art and science teachers' perspectives and experiences toward the collaboration of these two fields in education will hopefully provide a better idea of what the proposed emergent curriculum, Artistic and Scientific Knowledge, may look like for the future. In this section, I have articulated the pilot study procedures and data; I will cover the dissertation study in the subsequent section.

In order to better understand my two participants, the art teachers, I began by observing their classrooms. A glimpse into their teaching practices, interactions with students, and classroom environment provided me with guidance for my interview questions. I have included these observations in the Classroom Observations section. After observing the teachers' classrooms and interviewing them separately, I compiled the interview questions in the Data Collection section. Next, I thoroughly analyzed and interpreted the data, which is presented in the Data Analysis and Interpretation section. Last, I compiled themes from the data analysis, which are discussed in the Discussion/Conclusion section. This pilot study took place in the fall of 2014. The dissertation study was conducted in the fall semester of 2015 and the spring of 2016. I will discuss the procedures for the dissertation study in the succeeding section, The Dissertation Study.

Context.

The context of my study is two different art classrooms inside a public high school, serving grades 9-12, in a large suburban area outside a major metropolitan city.

The community is strongly supported, with high parent and volunteer involvement. This community is also very diverse and incorporates many ethnicities and cultures. Socio-economic status ranges from low to high, all within the same school district. The school district is one of the top districts in the nation, which makes this suburban area highly sought after by families. The high school setting of my study is quite large, serving about 4,000 students. These students are diverse and include: African-Americans, Asian-Americans, Caucasians/European-Americans, Hispanics, Middle-Easterners, Native Americans, and Pacific-Islanders. The teachers are of the same diverse ethnicities, with the majority being Caucasian/European-American. The school was renovated three years ago, so the facilities are up-to-date. The school is equipped with technology such as projectors, computers, iPads, and Smart Boards. There are many opportunities for students, including clubs, after school activities, and multiple electives such as art.

The Fine Arts Department includes visual art, music (marching band, orchestra, choir), dance, and theatre. The visual art program is large, with numbers of students growing each year. Within the visual arts, the areas taught are: Studio Art 1; Drawing 1, 2, 3; Painting 1, 2, 3; Ceramics 1, 2, 3; Sculpture 1, 2, 3; AP Art History; and AP Studio Art. There are four art teachers, including me. The art classrooms are equipped with seven to eight large tables each, and comfortably hold twenty-eight students. The students' cultures reflect the diversity of the school, particularly in the Studio Art 1 classes. The art classrooms have large amounts of storage comprised of cabinets, drawers, and back storage rooms. There is also a separate kiln room, which holds two kilns for ceramics. In addition, student art works are displayed on bulletin boards and in

display cases in the hallways connecting the classrooms. One hallway is decorated with a colorful mural that incorporates figures engaging in the visual arts.

Participants.

For the pilot study, two art teachers from the context above were selected, as a sample of convenience. Their names were changed to respect the privacy of these participants. Participant 1, whom I refer to as Joanna, has the following attributes: art teacher, female, Caucasian; specializes in ceramics and sculpture; ten years' experience in schools, both in the city and the suburban area; and one year experience at the high school in which the study is taking place. Joanna shared some perspectives on her teaching career:

> I love that I have experienced so many different school districts, teachers, administrators, and kids in my 10 year career. I've been at schools where my kids work hard and win every contest, and I've been at schools where my kids work their hearts out, and never win a thing. I've had administrators that support me, and ones who think art is a place to baby-sit the bad kids. I've worked with teachers that I admire beyond words, and ones that it felt impossible to work with. Each year has been challenging, wonderful, heartbreaking, tiring, exciting, and unique.
> Each summer I travel and rest, reflect, and begin to dream and prepare myself for what might be walking through my door the upcoming year.
> In 2015-2016 I will have 120 young people who get a brief 9-month experience to the joys of creating. After ten years that is 1,200 youth!

What a responsibility, what a gift. (Personal communication, June 2015)

After observing Joanna's classroom, which I detail in the next section, I felt the passion that she has for art, for teaching, and for her students. Her classroom was alive with dialogue and activity. Some of Joanna's personality traits, which are reflected in her teaching, are: kindness, humor, diligence, honesty, and dedication. Her open-mindedness gave me a refreshing outlook when constructing interview questions based on new curriculum ideas.

Participant 2, whom I call Helen, has the following qualities: art teacher, female, Caucasian; specializes in drawing and painting; 12 years' experience at the high school in which the study is taking place. Helen gave her perspective of her teaching career:

> [I] became an art teacher because it involved two necessities; Art and an income! Teaching has been a challenging career, mostly because the creative aspects of the job are vastly outweighed by all the administration and management. Trying to continue to develop as an artist while teaching full time with a family is challenging to say the least. (Personal communication, June 2015)

Following the classroom observation, I sensed Helen's more serious nature in her approach to art, teaching, and her students. Her classroom was much more quiet and calm than Joanna's. Helen's personality attributes, mirrored in her teaching, are: structure, detail-orientation, dedication, and honesty. Her realism and rationality helped to ground me as I constructed the interview questions, and reminded me of my teacher, not administrator, role in this study. New curriculum ideas, often imposed by administrators, look good on paper but do not translate well into practice (Rademaker,

2007). This rough translation often sways teachers away from new curricula and takes the joy out of teaching. My pilot study seeks teacher perspectives on my proposed curriculum to determine its feasibility in the classroom. I began with two art teachers for the pilot study, and will elaborate with more art teachers and also science teachers for my dissertation study, in The Dissertation Study section.

An ethnographic qualitative approach to the pilot study will allow the teachers to tell their stories, give their perspectives, and for me, as a teacher-researcher, to interpret their thoughts and behaviors. Other methods, such as surveys or statistical analyses may not provide such an in-depth look at the teachers and their everyday classroom experiences. Therefore, an ethnographic method was chosen for the pilot study, beginning with classroom observations.

Classroom observations.

My first observation took place in Joanna's art classroom on November 4, 2014, starting at 8:23am. The class period was fifty minutes long, and was a ceramics class. The demographics of the classroom were: twenty-five students, with seventeen girls and eight boys; mostly Caucasian students, with a few Hispanic students and one Asian student. I attempted to quickly record as much as possible; therefore my notes are in bullet-point form. These verbatim notes are as follows:

- She gathers class's attention; AP [Assistant Principal] comes in whistling, talks to class-disrupts class a bit, but very jolly-class interacts with him.
- Shows a video-tells class to focus-demonstrating about applying glaze to a vase-class quiet and focused. In the video she is demonstrating-she

makes comments while they are watching-kids very into it.

- She talks about stencils-she says it's a skill set they already have-easier to make mistakes on paper than clay pot.

- (Video has upbeat music; She made video this morning). She is upbeat and makes jokes. Then she asks if they have questions. She has vase in class-puts it next to her cheek-if it's cold it can't go into kiln.

- She points out a mistake on the vase and tells them how to fix it.

- Student makes comment that Joanna's pot is great-she wants that pot.

- She encourages questions. A student asks about their glass-Joanna explains that she researched and talked to ceramics experts and found out that [the] vent hood for [the] kiln doesn't work. This was upsetting-[I] can see emotion (sad) in her face.

- Then she tells kids to grab their pieces [clay pots] and they proceed to get pieces out-they follow directions pretty well-Joanna goes around and checks on them-interacts with them and gives feedback-describes particulars of pieces.

- Class gets bustling after a while-good amount of movement and activity.

- Student at my table asks for help-Joanna asks her to show her how she wants the handle of her pot. She gives feedback and shows her how to shape (braided) handle, how to fix imperfections, and then that handle should get leather hard, and the more the handle touches the vase the stronger it will be-mentions gravity when considering handle.

- Students all working diligently-everyone is on task.

- She works one-on-one with students-one girl seems unsure what to do-Joanna explains underglaze and carving.
- Joanna hands out sketches that they did beforehand-development sketches of their pieces with color and designs-mapping things out beforehand. [They] look at sketches and discuss the next steps of the project.
- Students are independent, self-directed. Joanna's not afraid to physically show them how to do things. Two girls discuss one's vase (at my table) – they get feedback from each other.

This observation was quite eye opening for me, as far as understanding processes in Joanna's classroom. Her teaching is a reflection of her personality – very lively and outgoing. Students are directed and then Joanna facilitates questions and assists with the projects where needed. She is knowledgeable and open-minded, and has a very collaborative nature.

My next observation took place in Helen's art classroom on November 5, 2014, starting at 8:24am. The class period was fifty minutes long, and it was a drawing class. The demographics of the classroom were: twenty-five students, with fourteen girls and eleven boys. Helen's class was a little more diverse than Joanna's, with Asian, African-American, Caucasian, and Hispanic students. My verbatim notes are listed below:

- [Helen's] recap [from the previous class period] – composition: 1) look at object across room-looks different than in front of you; 2) check values-

highlights and shadows; 3) look at details-look at overall levels instead of piece by piece; 4) still life in middle of room-she will take it down-they can take pictures if need to; 5) should be at burnishing stage-"finessing" [Helen's word].

- Project is on toned paper-using black and white blending pencils to draw parts of a still life.
- Helen asks if they have questions-doesn't give much time for them to answer, but two students (girls) come up to ask her things-one girl brings her project for feedback-teacher suggests adding shadows, but also points out positives.
- Students are independent-Helen points out time management-they only have two days to finish-so can trim the composition-she calls it "artistic license" where they make decisions so they can finish projects in time.
- Helen walks around and checks on students-asks how they're doing, how they're feeling-gives individual feedback; makes suggestions on how they can finish on time.
- Class is very quiet-students intently working on what they're doing. Helen has calming music playing (Spanish guitar). Not much movement of students-just getting up to take pictures of still life or sharpen pencils.
- One table-two boys-to one Helen comments that the boy "made things up" like he wasn't really looking at what he was drawing. [To] the other-she said be careful about outlining everything so it doesn't look too "pop-out cartoon" [Helen's words]. She makes suggestions and asks students

questions and if what she is saying makes sense.

- Helen talks to them about really looking at values-making distinctions between light and dark areas. Blending values together-holds up one student's piece so they can look at it farther away-talks about "visual interest" [Helen's words].

- "Large shapes of light and shadow" [Helen's words] (describing bark); to draw it [Helen says] figure out shapes of light and shadow and then go back and mark-make; mentions left-brain – your mind fills in the blanks of what marks are there.

- [Helen] talks to one student (boy) about time management. He is very detail-oriented so struggles with finishing [projects]. She mentions real life and time tables and bosses and deadlines.

- Last part of the project is "finesse time" [Helen's words] – looking at work with details.

This observation was quite eye opening for me, as far as understanding processes in Helen's classroom. Her teaching is a reflection of her personality – very rational and realistic. Students are directed and then Helen facilitates questions and assists with the projects where needed. She is knowledgeable and logical, pointing out realistic goals for her students.

After observing both classrooms, I noticed that the atmosphere of the two classes were very different. While Joanna's class was more laid back and comfortable, Helen's

class gave me the feeling of wanting to tiptoe around. Perhaps this difference came from the nature of the mediums, ceramic or drawing, as well as aspects of each teacher's personality. Nevertheless, I noticed a few concepts that each teacher discussed, which were science-related and which held potential for scientific explanations. I underlined these concepts in my observation notes. During Joanna's lesson, she mentioned that if the clay still felt cold it could not go into the kiln, as well as the descriptive clay term: leather hard. These facts relate to the process that clay undergoes from its natural state to being fired in the kiln. Scientific knowledge can explain the chemical reaction that occurs during this process; this supports the art concepts with science. In Helen's lesson, she discussed light and shadow and adding value (light and dark mark-making) to the drawing. She refers to the left-brain filling in the gaps between marks, which alludes to neuroscientific knowledge of the ways that the two hemispheres of the brain work together to process information. The potential for scientific connections from my observation data propelled my curiosity, which influenced my questions regarding scientific concepts in the art classroom. As previously mentioned, the personality traits and teaching practices of both teachers also influenced the formulation of my questions, namely Joanna's open-mindedness and Helen's realism and rationality. The next section details those interview questions.

Data collection.

To reiterate, the purpose of this pilot study is to bring teachers' perspectives to the forefront, and to encourage art and science teachers to collaborate. I address the research question: What are art teachers' attitudes/perspectives towards ASK teaching and

learning? After explaining the thoughts behind this proposed curriculum, namely the connection of artistic and scientific themes and concepts into one classroom, I interviewed the two art teachers. The interview questions relate to the main research question by addressing the teachers' views of ASK, of their current art teaching and whether it involves any scientific concepts, and of considerations of collaborations with science teachers. The interview questions that I asked my participants are as follows:

1) What is your perspective on Artistic and Scientific Knowledge (ASK) teaching and learning?

2) Do you use/talk about scientific concepts in your art classroom?

3) If yes, what kind of concepts and how? Do you specifically mention the word science to your students?

4) If no, would you consider talking about scientific concepts in relation to art? Why or why not?

5) Do you feel that teaching scientific concepts will hinder your art lessons in any way? Why or why not?

6) Do you believe science and art have commonalities? If so, what commonalities?

7) Are you interested in any artists who mix science into their artistic practice? If so, who? If not, have you considered artists such as these, why or why not?

8) Do you teach your students about these artists? If not, would you consider doing so? Why or why not?

9) Do you believe students would benefit from learning artistic and scientific concepts together? Why or why not?

10) Which branches of science, if any, do you feel would integrate with your teaching the most?

11) Would you be willing to pair up with a science teacher to do a lesson/lessons with each class (art and science)? Why or why not?

The observations that I have conducted are in the two different art classrooms in the suburban high school. As previously discussed, I have observed the teaching methods of the two art teachers, student learning, the behavior of both teachers and students, and the atmosphere of both teachers' classrooms. I have also been paying close attention to discover if these teachers integrate any scientific concepts into their art teaching and, if not, would they consider it.

Research findings: Data analysis and interpretation.

As part of the ethnographic approach to analyzing my data, I begin with a compare/contrast of my interviewees' responses as a way to look for emerging themes. I then use the analytical frameworks of pattern and triangulation to further analyze my data. I not only triangulate my interviewees' responses with the classroom observations that I make and my own interpretations as a fellow art teacher, but I look for patterns in their thoughts, behaviors, and experiences. I determine if their classroom teaching and behavior coincides with their thoughts and responses during the interview.

One reason why an ethnographic approach is appropriate for my research is that other research methods may not provide multiple interpretations and multiple perspectives. As Fetterman (2010) mentions, analysis can be the most creative step of ethnographic research: "the researcher synthesizes ideas and often makes logical leaps

that lead to useful insights" (p. 10). Another facet of the emic perspectives that ethnography uncovers is the recognition and acceptance of multiple realities (Fetterman, 2010). Also according to Fetterman (2010), "documenting multiple perspectives of reality in a given study is crucial to an understanding of why people think and act in the different ways they do" (p. 21). In my pilot study, discovering the different perspectives of the two art teachers helped me get a better sense of the multiple realities of the art classroom and prepare for the expanded study. While Artistic and Scientific Knowledge teaching has great potential, in my mind, I need to understand how my colleagues feel about its implementation. An ethnographic approach allows me to do this.

For my pilot study, I take the responses to each question from both art teachers and compare/contrast these responses. I have also observed both of their classrooms, so I can offer another insider's, or emic, perspective into the interpretations of the data. A few themes that emerged from this pilot study, through my interpretation, are that both teachers felt: 1) more time is needed to incorporate more science into the art classroom; 2) more training is needed to increase their scientific knowledge and to become better educated; 3) outside resources and/or assistance is needed to successfully accomplish art and science teaching/learning; 4) intimidation when considering the integration of scientific concepts into their lessons; and 5) on a more positive note, more motivation when thinking of the benefits to students with different skill sets. These emergent themes serve to provide an overview of the art teachers' thoughts and concerns with the proposed ASK curriculum.

More time for incorporation.

Question 1 (Q1): What is your perspective on Artistic and Scientific Knowledge (ASK) teaching and learning? Participant 1 (Joanna) looks at the bigger picture of the correlations between science and art, and the lack of understanding the younger generation has of the "science behind art". She mentions "old masters" (artists such as Leonardo da Vinci) and the more intimate relationship between scientific processes and artistic results. Joanna sees the connection between science and art, which used to be more prevalent before we got spoiled with commercialized art products. The "old masters" did not have the luxury of art supply stores with vast amounts of products. They understood how to use minerals and natural ingredients to make paints and other mediums. Participant 2 (Helen) looks at the smaller picture of the school setting. She goes straight to the response of it's not "viable" in the "current structure of education". Helen says she is "not opposed to the idea" but then states restrictions before even considering the possibilities.

More training for increased knowledge.

Q2: Do you use/talk about scientific concepts in your art classroom? Joanna interestingly mentions "high school level" science; and admits that it is not a strong suit of hers. She would "love to have more education" and then "would love to share more." This is already a positive outlook on the possibilities of art and science knowledge sharing. Helen has a more abrupt answer, "at times" and doesn't offer any further explanation of this answer.

Q3: If yes, what kind of concepts and how? Do you specifically mention the word science to your students? Joanna mentions the "best example" she can think of, and

actually ends up including one example in ceramics and two in sculpture. She seems more knowledgeable of these scientific concepts in relation to art than she previously realized. An interesting pattern surfaces after looking at Joanna's answers to the first three questions: Over time would Joanna's attitude change even more with more questions? Joanna opens up and thinks more about scientific concepts in art as more questions are asked. Helen includes three good examples from her classes, even after her short answer to question 2. She asks, "Does that count?" after two of these examples, which shows her uncertainty of science in relation to art – even though her examples show otherwise. Neither teacher answered if they specifically mention the word science to their students. Perhaps I should rephrase the question, or perhaps they will mention science now that the seed is planted by these questions.

Q4: If no, would you consider talking about scientific concepts in relation to art? Why or why not? Joanna mentions again being "better educated" and looks at the bigger picture when she says, "It would be a great way to get kids with other interests involved." Helen again mentions being "not opposed" and more abruptly says she "can't talk about things [she doesn't] know or understand;" even though in the previous response she already talks about science in relation to art and understands it from her own research. Perhaps she feels more intimidated?

Outside assistance needed.

Q5: Do you feel that teaching scientific concepts will hinder your art lessons in any way? Why or why not? Joanna feels that this will not hinder her art lessons because she "would like to add fun correlations and facts". She interestingly mentions "entire science objectives" – this is something I did not consider from the art teacher's point of

view. A science teacher or resource specialist in this possible new collaboration of fields would need to provide specific science objectives. Would we stick to the existing science/art TEKS and use science in the art classroom and vice versa to supplement those TEKS, or would we come up with a whole new set of TEKS for a new art and science field/curriculum? Joanna also mentions the existing incorporation of "writing, math, history, and other subjects" to art, so "adding science would be great". Her response does not show any intimidation. Helen, on the other hand, says that it will hinder her lessons because "without any change in the current teaching structure it would be just one more thing to do." She previously mentioned not being opposed to the idea, but now reverts back to the restrictions of the school setting.

Q6: Do you believe science and art have commonalities? If so, what commonalities? Both teachers answered, "Yes" to this question. Helen, however, elaborates more and now looks a little more at the big picture. She doesn't think "compartmentalizing everything separately is always the most effective way to teach." This suggests that she thinks the possibility of ASK teaching and learning would be effective for students, but then she again mentions public education as a "big bureaucracy" that would hold the idea back from implementation.

Q7: Are you interested in any artists who mix science into their artistic practice? If so, who? If not, have you considered artists such as these, why or why not? Joanna mentions a specific artist and even shares his website. Helen mentions a "NASA artist" but says she has never taught about this artist. She mentions that other "contemporary artists" must be out there, but she is not familiar. The next question delves a little deeper into teaching about these artists.

Q8: Do you teach your students about these artists? If not, would you consider doing so? Why or why not? Joanna says enthusiastically that she does teach about a specific artist every year and the kids love it. Helen's response fits more into the school structure with the mention of fitting into a lesson plan. She generalizes more by saying that in an ideal situation, "each lesson should have an artist exemplar." The two answers reflect the flexibility of Joanna that I felt when observing her classroom, and rigidity/structure of Helen that I felt when observing hers.

Q9: Do you believe students would benefit from learning artistic and scientific concepts together? Why or why not? Joanna interestingly mentions the validation of the arts by correlating to other content areas. Helen's answer is much longer, and she still centers on the teacher and not the students. She mentions the "current structure" of the school again. This is a recurring theme with her. She talks about a possible collaboration with a math teacher a few years back, but that the idea was not followed through because of the lack of time and because teachers have their own separate classes. Helen also mentions the "roving art teacher" – an outside person who specializes in developing art lessons with other subjects. The recurring theme of training and resources comes back when she says, "For an art teacher to teach scientific principles in her own room, she would need training and ready to go handouts. And that is presuming she understands the material." Helen's response reflects her realistic and straightforward nature. She was this way with the students when I observed her class – she does not sugarcoat things.

Feelings of intimidation.

Q10: Which branches of science, if any, do you feel would integrate with your teaching the most? Joanna gives nine examples of branches of science that would

integrate with art. These are: biology, chemistry, physics, astronomy, environmental science, anatomy, aquatic science, forensics, and geology. I find it interesting that she was quite specific about this, considering that she didn't think she was very knowledgeable about science. Perhaps she is thinking about the possibilities more and more. Helen surprisingly (even to herself) mentions math in art. It is interesting that she didn't try to think about science – she just thought about the math that she refers to in her sighting and drawing lessons. The intimidation of lack of science knowledge may be affecting her answers.

Increased motivation – benefits to students.

Q11: Would you be willing to pair up with a science teacher to do a lesson/lessons with each class (art and science)? Why or why not? Joanna mentions time outside of the classroom to be able to do this, but that she is willing. Helen says that she is willing as well, but also mentions the outside support. She finally opens up about the benefit to the students, saying that she thinks it could be very interesting and that the "kids would love the cross over." She says that she would need a little "prodding" because she has seen a lot of programs come and go. But this response shows an interest on her part and a willingness to try with the proper help/resources provided.

Overall, these responses gave me insight into the perspectives of my colleagues as well as crucial aspects to consider for the success of the ASK curriculum. As previously discussed, new ideas and concepts for art education may function better in theory than in practice. Therefore, the findings of this study provide realistic views of the potential success of ASK before implementation is solidified.

Implications of findings.

The use of the ethnographic approach allows the researcher to uncover the thoughts and behaviors of the research participants. The rationale for my study includes understanding the perspectives of other people in my field concerning the implementation of a new approach to Artistic and Scientific Knowledge (ASK) teaching and learning. I need to understand the thoughts and perspectives of my colleagues to understand whether or not a new curriculum will be accepted. After analyzing my data, I offer my interpretations as well as include the verbatim quotations of my research participants. This is so readers can form their own interpretations of the data, allowing for more multiple realities to be brought forward, as Fetterman (2010) recommends.

After reading Fetterman's (2010) account of theories behind ethnographic research, I found both ideational and materialistic theory useful. He explains, "cognitive theory is the most popular ideational theory in anthropology today. [It] assumes that we can describe what people think by listening to what they say" (Fetterman, 2010, p. 6). Also, according to Fetterman (2010), ethnographers who "adopt materialist theories view the world according to observable behavior patterns" (p. 6). In my pilot study, I adopted both of these approaches: a cognitive approach to listening to what the teachers said and then interpreting their thoughts; and a materialist approach to observing their behavior patterns in their classrooms. These types of information can successfully be gathered through the ethnographic methodological approach.

Through my analysis of the pilot study, I discovered that the perspective of one of the art teachers changed as she answered more questions. As she thought more about the possibilities of art and science together, she seemed to regret the prior, somewhat

negative perspective that she first gave. Also, the questions enabled both teachers to think more about their own teaching and the possibilities of new collaborations. While analyzing the data, I looked for patterns in the thoughts and behaviors of the two art teachers to uncover common themes. As previously mentioned, the themes that emerged from this pilot study through my interpretation are that both teachers felt: 1) more time is needed to incorporate more science into the art classroom; 2) more training is needed to increase their scientific knowledge and to become better educated; 3) outside resources and/or assistance is needed to successfully accomplish art and science teaching/learning; 4) intimidation when considering the integration of scientific concepts into their lessons; and 5) on a more positive note, more motivation when thinking of the benefits to students with different skill sets.

Through this research, I hope to fill the gaps in the literature mentioned beforehand with more of the actual perspectives of art teachers regarding the incorporation of science into their classrooms. There have been collaborative projects done, but ethnographic research can provide the emic perspective that is usually unstated. I hope to continue uncovering art and science teachers' perspectives regarding the collaboration of the two fields. For me, analyzing the thoughts, behaviors, and experiences of others in my field has really helped me to understand the voices of those more experienced than me. Ideally, I want my idea of Artistic and Scientific Knowledge (ASK) to succeed, but there are many steps in the journey that this ethnographic qualitative research has shed light on. My pilot study is the first step, which has revealed two art teachers' views of the feasibility of an ASK curriculum. The dissertation study adds one more art teacher's and also science teachers' perspectives. In proposing a new

curriculum idea, it is important to ascertain the views of those, such as teachers, who will be involved in its development. The aim of my dissertation study is to not only reveal these valuable perspectives, but also to discover more of the curriculum development process itself.

This qualitative case study is significant to teachers, administrators, and curriculum designers within all levels of art and science education. More often than not, art education is seen as less necessary than other subjects, such as math and science, for student success in the real world (Eisner, 2002). Through research, analysis, and interpretation of art and science collaborations, both in schools and in the real world, I have discussed the positive implications that art has had on science teaching and learning and vice versa. By showing administrators, teachers, and students the value of artistic thinking outside of the art classroom, new understandings of art education are brought to the forefront. I have too often heard misconceptions of art education as merely classes purely to paint pretty pictures or make cute projects. There is so much more to art education and, through collaborations with science education, twenty-first century thinking is more strongly supported and utilized.

Successful results of art and science education collaborations are encouraging to teachers, administrators, and curriculum designers who are reinventing or redesigning curricula to fit twenty-first century thinkers (Needle et al., 2007). Our globalized, highly technological society requires students to embrace multiple ways of inquiry and interpretation. By connecting art and science in the school setting, art and science teachers can better prepare students for the real world. For these collaborations to work, teachers need to be on board and open to new ideas. My research findings, thus far,

demonstrate that teachers are adaptive to new situations. Even though Helen was more resistant at first, she began to change her perspective after exploring the ASK curriculum idea. These teachers' viewpoints are vital because teachers often feel left out in the process of reinventing curricula. Through collecting, analyzing, and interpreting data that centers on teachers' perspectives, I hope that they see their valuable place in this curriculum development process.

My dissertation study includes, as mentioned previously, another art teacher as well as three science teachers in this qualitative research. The science teachers provide crucial perspectives in the process of developing ASK, a complimentary scientific approach to the same questions asked of art teachers. It seems that ethnographic research may not be common among the scientific community. However, just as art and science can cross boundaries, so can scientific inquiry and ethnography, which examines the people who are fundamental to the student experience in education: the teachers.

The Dissertation Study

Procedures of inquiry.

For my dissertation study, participants were selected from my high school. I have selected these teachers as a sample of convenience: they are in close proximity to me at the high school. I have included six teachers from the two disciplines: three art teachers (two of whom are from the pilot study) and three science teachers. If art and science are to be taught in tandem, then it is important to gain the attitudes and perspectives of teachers from each discipline. I began by visiting with my participants, the science teachers and the art teachers, in their classrooms. I am familiar with the art teachers'

classrooms because I frequent them often. However, I felt like a foreigner in the science classrooms so one of my goals, as an art teacher and researcher, was to become better acquainted with that side of the school. Through email and a visit to each science classroom, I have formed connections with the science teachers. In brief meetings with each science teacher, I explained the ideas behind my research and got to know them a little better. Similarly, I spoke with each art teacher about my research. I described to my two pilot study participants, Joanna and Helen, how my research question has progressed since that initial study.

After conducting the pilot study, it was evident that I needed a more broad approach to my interview process. Although the art teacher's perspectives provided great insight for my research, I realized their difficult task of generating responses regarding a curriculum that has not yet been developed. In order to attain a clear idea of an ASK curriculum, I need to first comprehend teachers' perspectives of art and science integration in education. Therefore, I arranged two interviews with each teacher in their own classroom. The first interview focused on specific questions about art and science integration, while the second included viewing, analyzing, and discussing images of scientific art. I recognize that I am biased toward art and science integration and collaboration. As an art teacher and researcher, I am the research tool in the setting of my high school. This setting is important for ethnographic qualitative research, which evolves best in the natural setting of the participants – the art and science teachers. Therefore, it is vital that I understand my biases and ensure that I try my best not to influence my interviewees with my viewpoints. I have objectively conducted the interviews and conversations, as well as audio-recorded the conversations for accuracy of

data collection. First, I have compiled the interview questions and the scientific art images in the Data Collection section of this chapter. Next, I thoroughly analyzed and interpreted the data, which is presented in the Data Analysis and Interpretation section of this chapter. Last, in the next chapter (Chapter 4), I compiled themes from the data analysis, which are discussed in the Triangulation of Data and Emerging Themes section. The dissertation study took place in the fall semester of 2015 and the spring of 2016.

Context.

The context of my study includes the two art classrooms from the pilot study and four additional classrooms, one art and three science classrooms. These are inside a public high school, serving grades 9-12, in a large suburban area outside a major metropolitan city. (The Context section in Chapter 1 includes the detailed description of the school.) The Fine Arts Department includes visual art, music (marching band, orchestra, choir), dance, and theatre. The visual art program is large, with numbers of students growing each year. Within the visual arts, the areas taught are: Studio Art 1; Drawing 1, 2, 3; Painting 1, 2, 3; Ceramics 1, 2, 3; Sculpture 1, 2, 3; AP Art History; and AP Studio Art. There are four art teachers, including myself. The art classrooms are equipped with seven to eight large tables each, and comfortably hold twenty-eight students. The students' cultures reflect the diversity of the school, particularly in the Studio Art 1 classes. The art classrooms have large amounts of storage comprised of cabinets, drawers, and back storage rooms. There is also a separate kiln room, which holds two kilns for ceramics. In addition, student art works are displayed on bulletin boards and in display cases in the hallways connecting the classrooms. One hallway is decorated with a colorful mural that incorporates figures engaging in the visual arts.

The Science Department at the school is large, with subjects that include: IPC (Integrated Physics and Chemistry), Biology, Chemistry, Anatomy, Forensics, Physics, Environmental Science, and Aquatic Science. Of the science teacher participants, two teach Chemistry and one teaches Physics. The Chemistry classrooms are large in size and can comfortably seat thirty students. There are individual desks in the center of the rooms, and bar-type tables perpendicular to the counters aligning the sides of the rooms. These bar tables each have a sink in the middle and two stools under them. These tables are where students conduct their lab activities for the class. There is ample storage in the rooms (cabinets and counter space) as well as efficient technology (computer and smart board). The Physics classroom is quite similar, only the bar-type tables are not fitted with sinks and are used in place of desks. The bar tables each have two stools under them. The sinks are located in the counter at the back of the room. The teacher has a computer but no smart board. Instead he has white boards at the front of the room and a portable white board at the back of the room. There is also ample storage in the room, with cabinets and counter space. These science rooms are all neatly kept, and there is very minimal decoration compared to the art rooms.

Both the art and science classrooms utilize space for activities. The art classrooms only have four-person square tables, while the science classrooms have desks and two-person rectangular tables. Both sets of classrooms have countertops with sinks for projects/labs. The art and science rooms both have ample storage cabinets, but the art classrooms have large drawers as well. The science classrooms are very minimally decorated. In contrast, all of the art rooms have posters, graphics, framed art, sculptures, and student artworks that adorn the walls and the tops of the cabinets. This creates an

airy type of feeling in the art classrooms because there is a lot of color to contrast the white walls and wood cabinets. In the science classrooms, the cabinets are black so it almost feels heavier and more serious without the colorful decorations that I'm used to in the art rooms.

Participants.

For this dissertation study, three art teachers and three science teachers from the context above have been selected, as a sample of convenience. Their names have been changed to respect the privacy of these participants. Participant 1 and Participant 2 were a part of the pilot study. Participant 1, whom I refer to as Joanna, has the following attributes: art teacher, female, Caucasian; specializes in ceramics and sculpture; ten years' experience in high schools, both in the city and the suburban area; and one year experience at the high school in which the study is taking place. Participant 2, whom I call Helen, has the following qualities: art teacher, female, Caucasian; specializes in drawing and painting; twelve years' experience at the high school in which the study is taking place. Participant 3, whom I name Lisa, is also an art teacher, female, and Caucasian; she specializes in painting and has two years' experience at an elementary school in the city; and one year experience at the high school where the study is occurring. Participant 4, whom I call Jennifer, has the following characteristics: science teacher, female, Caucasian; five years' experience at a junior high school in the same school district; and eighteen years' experience at the high school where the study is taking place. Participant 5, whom I refer to as George, possesses these attributes: science teacher, male, Caucasian; eight years' teaching experience in a city high school; twenty-

nine years' of experience at the study's high school. Finally, Participant 6, whom I call Ralph, is also a science teacher, male, Caucasian; and he has seven years' teaching experience in a city high school, one year experience at an art college in the city, and seven years' experience at the high school in which the study is taking place.

This group is quite diverse, with the teachers' experience ranging from three years to thirty-seven years in the classroom. Each teacher's personality was different; however, the science teachers shared a more direct, straight-to-the-point approach to my questions, while the art teachers seemed to brainstorm frequently as they responded. All of the teachers drew from their own experiences when thinking of the opposite subject, art or science; and all but one art teacher showed a real curiosity to learn more. Both the art teachers and the science teachers displayed a willingness to collaborate on a joint curriculum.

Data collection.

To reiterate, the purpose of this research is to bring teachers' perspectives to the forefront, to encourage art and science teachers to collaborate, and to gain insight into the development of the ASK curriculum. I address the following research question: What are the perspectives of art teachers and science teachers regarding the integration of art and science in education? After reflecting upon the observations from the pilot study, I have determined that more observations than time will allow are necessary to discover any art and science integration in these classrooms. If the teachers had not considered art and science integration prior to this study, then the amount of integration is most likely minimal and would require many more observations to uncover this small amount of

data. Therefore, I have opted for a more direct approach due to the purpose of my research as discovering teachers' perspectives.

In my dissertation study, I interviewed each science teacher and art teacher in their classrooms, in order to discover their perspectives on art and science integration in education. I determined if they have or would consider this approach through the interview questions. Subsequently, I had a conversation with each teacher based on images of scientific art. This process enabled me to uncover more about the personalities and thinking processes of each teacher. It also, in combination with the interview questions, assisted in forming a better idea of the proposed ASK curriculum. Bresler (1991) elaborates,

> When the study is that of a culture to which the researcher belongs, there is a deliberate attempt to notice everyday events in a fresh light. The issues are progressively focused and the direction of the issues and foci often emerge during data collection and analysis. (p. 7)

This attempt to notice everyday events in a new light is important to the school setting and can encourage new thoughts and ideas.

After explaining the thoughts behind my research, namely the integration of artistic and scientific themes and concepts in education, I interviewed the six participants. The interview questions relate to the main research question by addressing the teachers' views: of art and science in general, of the integration of the two disciplines, of their current teaching and whether it involves any artistic/scientific concepts, and of collaborations with other art and science teachers regarding integrated curriculum development. The interview questions that I asked my participants are as follows:

1) Please state your name and occupation.
2) How long have you been teaching?
3) Have you taught at other schools besides this high school? If so, where and what age group?
4) Have you taught any other subjects besides science [art]? If so, which subjects?
5) Please tell me your thoughts on visual art [science], like that which you would see in an art [science] museum. What comes to mind when you think of art [science]?
6) Do you have an interest in the arts [sciences] or in learning more about the arts [sciences]? Please explain.
7) Do you believe that art and science have commonalities? If so, what kinds of commonalities?
8) What do you think about the integration of art and science? Integration or specialization of these two subjects?
9) Do you integrate art/artistic concepts into any of your science lessons? [Do you integrate science/scientific concepts into any of your art lessons]? If yes, what kind of concepts and how? If no, would you consider doing so, why or why not?
10) Do you believe students would benefit from learning artistic and scientific concepts together? Why or why not?
11) Would a curriculum that focuses on integrating art and science be feasible in the high school setting? Please explain.
12) Would you be willing to collaborate with other science and art teachers to help develop ideas for such a curriculum?

After these first interviews, which lasted about 50 minutes, I followed up with another 20 minute conversation with each participant. These discussions centered on eight images of scientific art that I showed each teacher. I asked each participant to share her/his thoughts about the individual images. I then gave a description, in the artist's own words, of what each image explored; and asked the teacher to share any further perspective on what they were viewing. These conversations were very interesting and quite exciting; and spurred further brainstorming of curriculum ideas and reflection on the integration of art and science. While researching online, I conducted a search for scientific art. The images that I selected are a part of some of the first results displayed by my search engine. I studied the images and their descriptions, and I chose a variety of subject matter to show the teachers. These scientific art images all come from art competitions held by the University of North Carolina (UNC) at Chapel Hill (http://chanl.unc.edu/scientific-art/), and are as follows:

Image 1: *Skyline in the Snow* by Aleksandr Zhushma from the UNC Department of Chemistry.

The artist for Image 1 describes it by saying, “This image was made by accident when a mixture of particles in a salt solution dried. The straight lines and angles [are] because of the crystal structure of salt when it dries. The original image was taken in black and white with a light microscope – color added in image” (Zhushma, 2015). This image reminded the scientist/artist of the New York City skyscrapers peeking through a hazy blizzard of snow falling on the city (Zhushma, 2015).

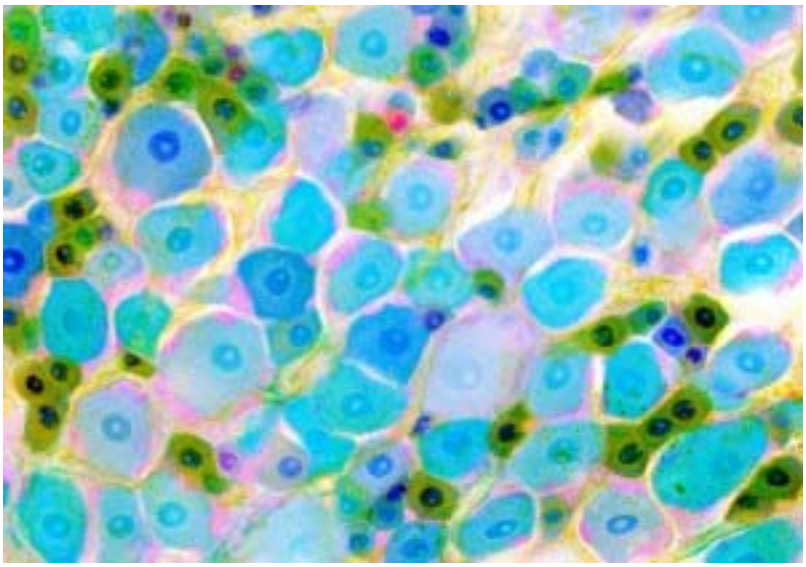

Image 2: *Easter Basket* by Bonnie Taylor-Blake and Brandon Pearson from the UNC Department of Cell Biology and Physiology.

Image 2 is explained as, “The dorsal root ganglion [in the spinal cord] contains sensory neurons that detect stimuli from the environment which then send these signals to the spinal cord and brain” (Taylor-Blake and Pearson, 2015). I further paraphrased their words to my participants, detailing that the green neurons contain a different gene than the others that are light blue and dark blue. This image was taken with a microscope as well.

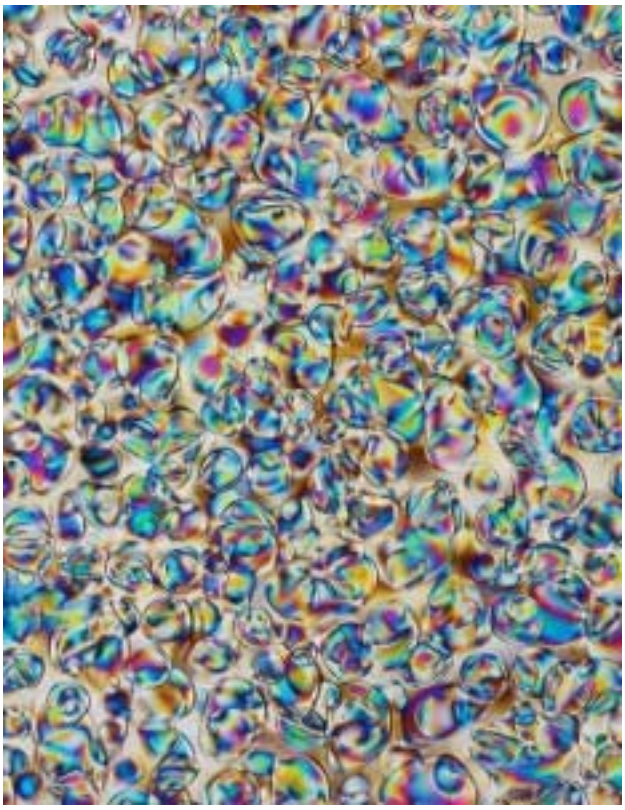

Image 3: *Rainbow Bubbles* by Sara Turner, Stephanie Liffland, and Valerie Ashby from the UNC Department of Chemistry.

> Image 3 is elaborated on by the artists in the following statement:
>
> In our current digital age we find ourselves surrounded by liquid crystals in places like our phone, our TVs, and our computer screens. These special molecules contain special light-bending characteristics that cause interesting rainbow patterns when viewed with polarized light. The liquid crystalline material here is being investigated for use in battery applications (Turner, Liffland, and Ashby, 2015).

This intriguing image was taken with a microscope using a polarized light filter, similar to how polarized sunglasses help us to see rainbow effects in the sky.

Image 4: *Snowflake Robe* by Maria Ina and Aleksandr Zhushma from the UNC Department of Chemistry.

Image 4 is described by the creators as a, "… fractal-like spot was seen with an electron microscope. Some material crystallized on the surface, like ice crystallizes on a window. The surface on which it lay had a wavy structure, giving it a flowing, robe/curtain-like, appearance" (Ina and Zhushma, 2014). It is amazing that this image was something so small that a microscope is necessary to view it this way. It conjures up ideas of ice forming on a car windshield on a cold morning. However, we would not see the ice as intricate snowflakes, with our naked eye alone.

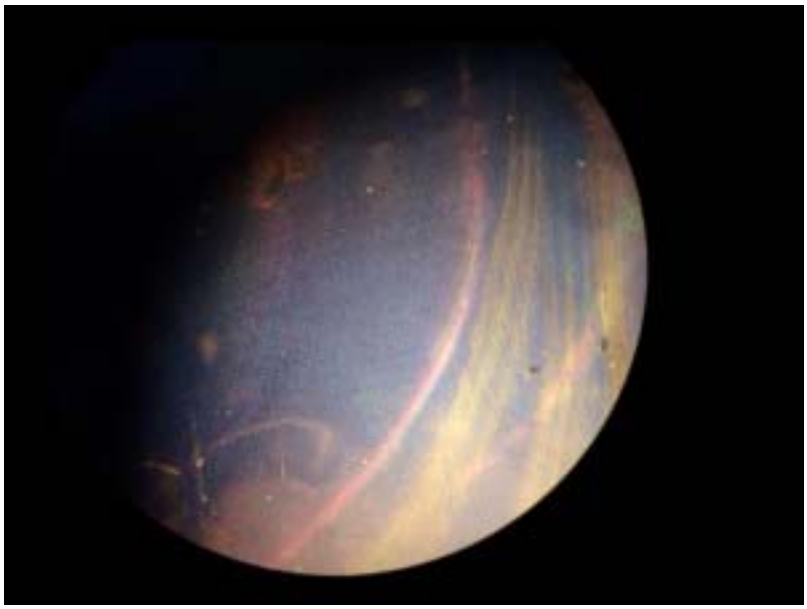

Image 5: *Nano World* by Cary Tippets, Yulan Fu, and Rene Lopez from the UNC Department of Physics and Astronomy.

> Image 5 is explained:
>
> As viewed through the eyepiece of a confocal microscope [which increases optical resolution], this world was crafted from a transparent polymer, and is covered by small tree-like structures. This brilliant blue color is not produced by pigment but from these small structures on the surface. These tree structures interact with the light and only reflect the color that you see (Tippets, Fu, and Lopez, 2014).

While many viewers' first instinct is to call this image a planet, these scientists/artists have created something much smaller. Rather than looking through a telescope at a far away world, one is looking at a tiny, carefully crafted world under a microscope.

Image 6: *Carbonic Cluster* by Mike Sonnichsen from the UNC Department of Art.

> This colorful Image 6 is elaborated on by the artist in the following statement: This image is one in a continuing survey of familiar plastic objects, in this instance, a double-exposure of two arrays of translucent cola cup lids. The recording was made using analog photographic materials (color photo paper and light) and the colors are the compliments of those seen in visible light. While not representing the nano-scale, this process may reveal previously unseen qualities of our material world, and momentarily confound, engage, or dazzle the viewer (Sonnichsen, 2013).

This artwork is an intriguing way to encourage viewers to reflect on our carbon footprint that we leave on this planet.

Image 7: *Year of the Dragon* by William Rice, from the UNC Department of Physics, and Robert Schmidt and Robert Bruce from the UNC Department of Chemistry.

Image 7 is described as, “Unique patterns of crystalline growth of valence tautomer out of a dichloromethane solution. Crystal branches grow out onto a planar surface but turn to avoid growing into one another. When they cannot grow any further, they collapse into spiral shapes forming dragon heads” (Rice, Schmidt, and Bruce, 2012). This image captures the fascinating growth patterns of crystals in a solution. It can remind the viewer of many different images, from wallpaper to weaving, but sheds a unique light on a scientific process.

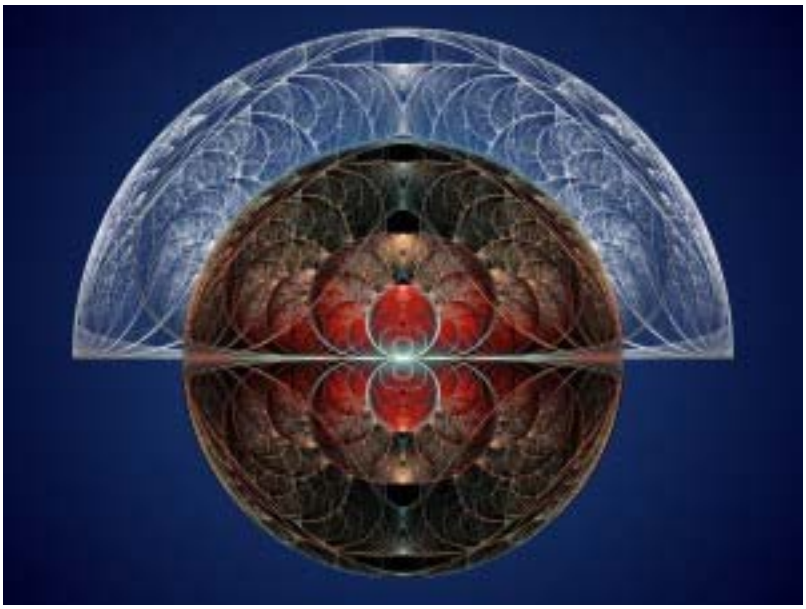

Image 8: *Don't Forget Your Umbrella* by David A. Barrow, PhD. from the UNC Cytokine and Biomarker Analysis Facility/NC Oral Health Institute.

Image 8 is explained by the artist as follows:

This digital artwork was created with a fractal software program called Apophysis, which can generate "IFS Fractal Flames". IFS stands for Iterated Function System, a relatively new branch of mathematics. Fractal patterns often resemble structures in nature, and many viewers enjoy identifying familiar plants or animals, similar to "cloud watching". The delicate lines in this image are similar to the vein patterns found in leaves (Barrow, 2014).

Data analysis and interpretation.

As part of the ethnographic approach to analyzing my pilot study data, I began with a compare/contrast of my interviewees' responses as a way to look for emerging themes. I then used the analytical frameworks of pattern and triangulation to further

analyze my data. I not only triangulated my interviewees' responses with the classroom observations that I made and my own interpretations as a fellow art teacher, but I looked for patterns in their thoughts, behaviors, and experiences. I determined if their classroom teaching and behavior coincided with their thoughts and responses during the interview. For my dissertation study, I use the same analytical frameworks of triangulation and pattern, from the pilot study, to analyze the responses of the science teachers and the art teachers. As a next step, I use these frameworks to compare and contrast the art teacher data with the science teacher data. I also integrate the art teacher data from my pilot study into this overall data analysis and interpretation. Finally, I triangulate the perspectives of art teachers with those of science teachers and with that of my own perspective. In addition, I have taken the participant responses to the scientific art images and compiled these into eight tables, one for each image. Each table includes the artistic aspects and the scientific aspects of the image, as mentioned by each teacher; as well as his/her perspective of the image. I then analyzed these data to look for commonalities in the thinking processes of the art teachers and the science teachers; and to gain further teacher perspective regarding art and science integration and collaborations. These analyses heed some very interesting conclusions for the partnership of art and science in the classroom. These conclusions allow me to better understand the prospect of art and science teacher collaboration; and to provide a better idea of what the ASK curriculum may look like, and if it is feasible for implementation in the high school setting.

Chapter 4

Research Findings and Analysis

Structure

I have organized this chapter in sections, which include the research participants' responses to the interview questions. The first section, Teacher Experience, contains questions 1 through 3. The second section, Teacher Thoughts and Interests, reports responses to questions 5 and 6. The third section, Art and Science Commonalities and Integration, includes answers to questions 7 through 9. The fourth section, Art and Science Concepts and Curriculum, presents replies to questions 10 through 12. Finally, the fifth section, Scientific Art Image Conversations, comprises the discussions between each participant and myself regarding scientific art images 1-8. Subsequently, I present the analysis of these data according to this same grouping of responses.

Teacher Experience

To reintroduce the participants, I have grouped their responses to interview questions 1, 2, and 3 together. Participant 1 (Joanna) is an art teacher who specializes in ceramics and sculpture; has ten years' experience in high schools, both in the city and the suburban area; and has one year experience at the high school in which the study is taking place. Participant 2 (Helen) is an art teacher who specializes in drawing and painting; and has twelve years' experience at the high school in which the study is taking place. Participants 1 and 2 were also a part of the pilot study. Participant 3 (Lisa) is an art

teacher who specializes in painting; has two years' experience at an elementary school in the city; and has one year experience at the high school where the study is occurring. Participant 4 (Jennifer) is a science teacher; has five years' experience at a junior high school in the same school district; and has eighteen years' experience at the high school where the study is taking place. Participant 5 (George) is a science teacher; has eight years' teaching experience in a city high school; and has twenty-nine years' of experience at the study's high school. Participant 6 (Ralph) is a science teacher; and he has seven years' teaching experience in a city high school, one-year experience at an art college in the city, and seven years' experience at the high school in which the study is taking place. In sum, Joanna, Helen, and Lisa are art teachers 1, 2, and 3, respectively. Helen has the most teaching experience, followed closely by Joanna. Lisa has the least teaching experience of all of the teachers, including science. Jennifer, George, and Ralph are science teachers 1, 2, and 3, respectively. George has the most teaching experience, followed by Jennifer, and then Ralph. George has the most teaching experience of all the teachers, including art.

Question 4 (Q4): Have you taught any other subjects besides science [art]? If so, which subjects? To clarify, the science teachers were asked this question regarding science; and the art teachers were asked the same question, with the exception of the word art replacing the word science. Joanna has not taught other subjects besides art, but she did coach soccer for four years and had a "soccer class period". The specific art classes she has taught include: Studio Art 1, Drawing 1 and 2, Advanced Placement (AP) Art History, AP Studio Art, Sculpture 1, 2, 3, and 4, AP Sculpture, Ceramics 1, 2, 3, and 4; and she has lead the National Art Honor Society (NAHS) chapters throughout all her

years of teaching. Currently, Joanna is teaching the sculpture and ceramics classes, and leading the NAHS. Helen also has not taught other subjects than art. Her art classes comprise: Studio Art 1, Drawing 1, 2, and 3, Painting, AP Art History, and AP Studio Art. At present, Helen instructs Studio Art 1, Drawing 1, 2, and 3, and AP Studio Art. Lisa has only been a teacher of art, encompassing elementary art, Studio Art 1, and Painting 1, 2, and 3. Presently, she teaches the Studio Art 1 and Painting classes; in addition, she coaches high school softball. Jennifer has instructed one year of reading, but otherwise all science. She says that the "reading was not by choice" and that she "absolutely prefers science." Jennifer currently teaches Chemistry and is the science department chair. George has only instructed science classes. These classes include: AP Biology, Integrated Physics and Chemistry (IPC), Astronomy, Aquatic Science, Environmental Science, academic Chemistry, Pre-AP Chemistry, AP Chemistry, and academic Physics. He was also the science department chair at the study's high school for thirteen years. At present, George is teaching academic Chemistry and Pre-AP Chemistry. Ralph has taught a math class and a physics class at a local art college, but otherwise has always taught high school science. Presently, he is teaching AP Physics at the high school where my study is taking place.

All of the teachers in this group, except Lisa, have more than ten years' experience teaching either art or science. Two of the science teachers have greater than twenty years' experience in the science classroom, with most of those years taking place at the study's high school. Both the art teachers and the science teachers have either taught different grade levels or varieties of art classes/science classes. These years of teaching experience are reflected in the participants' interview responses. The teachers

with a greater variety of exposure to different classes, schools, and approaches possess a stronger curiosity and open-mindedness to art and science integration. This is a commonality that crosses the subjects' boundaries, and is encouraging for me as I contemplate a non-traditional curriculum (ASK).

Teacher Thoughts and Interests

Question 5 (Q5): Please tell me your thoughts on visual art [science], like that which you would see in an art [science] museum. What comes to mind when you think of art [science]? Joanna (art teacher 1) contemplates and says,

> I think back to when I took science classes, so I'm really fond of having a hypothesis, and coming up with theories and testing those theories. I think of labs, dissecting things, and learning anatomy - from the microscopic to the big picture. I think of science in terms of astronomy, of space. I think of science, for some reason, as being hard but interesting. (personal communication, March 3, 2016)

I ask her why she thinks of science as being "hard"? She responds, "It would just be because there were so many tests and so much memorization – that part, for me, was always hard. But the labs, testing and dissecting things, going outside and looking at the stars – that part I always have fond memories of" (Joanna, personal communication, March 3, 2016).

Helen (art teacher 2) states, "To me, science is – well you have the natural sciences like biology, physics, engineering, it can be mathematics, so it's widespread. It's a very large category without classifying it in some way. I think it's pervasive"

(personal communication, March 1, 2016). I have to explain the question further and encourage her because she wasn't quite sure how to answer. Helen elaborates,

> I mean they're all sciences but one is pursuing the natural world and one is pursuing a mathematical approach. My husband is a scientist – chemical engineer – it's very practical, very useful. I see it as extremely important, personally I admire those people. There's the theoretical which is actually quite creative; then there's the concrete; then there's the classification and discovery. I think science is really cool; I think it's everywhere and I don't see it as being isolated. (personal communication, March 1, 2016)

In addition, she mentions that she loved biology in school and loves learning about plants. Helen (personal communication, March 1, 2016) adds, "I'm interested in things on more than just a beautiful level. For example, I love flowers, but I like knowing what's the best way to make them grow, what soil do they need, what bugs they attract – so you start getting into the biology and things like that, so I just don't see science as segregated."

Lisa (art teacher 3) answers, "First thing is that it [science] always bored me – I was never intrigued by it. The only things I was intrigued with were creating things, and I felt that was something that was pulled through the artistic, creative side of me." She mentions that it was neat to see "all that kind of stuff in my face" at a museum; but felt differently about science classes in school: "it was just a class that I went through, but I knew that there were aspects of it that helped us understand the world and make things go round" (personal communication, March 2, 2016). Lisa expands these thoughts,

> It's always the left side and the right side of the brain – I was always more

> of the right side. I tried but it [science] never really intrigued me as much. There were parts of it that were interesting, but it was kind of forced on me. Natural science was more interesting: different layers of the earth, Pangaea, the dinosaurs; aspects of physics, and creating chemical reactions. But I always felt like there were so many other things that came into it that were hard for me to grasp. Anything that had to do with an equation, I avoided. (personal communication, March 2, 2016)

I ask if she meant that she avoided the math aspects of some sciences, and she responds, "Oh yeah, math, so I guess not so much science" (Lisa, personal communication, March 2, 2016).

Jennifer (science teacher 1) states, "Unfortunately, I'm not very artsy, it's so not my brain. So I look at it [art], and a lot of it I think is pretty; a lot of it I think is weird; most of it I don't get. It's just really out of my realm, and I don't really frequent museums, especially art museums. If I go, it's more to the natural science museum" (personal communication, February 5, 2016). She tries to think of more, saying, "What else? I think rich, I think creative, I think – my brother has a lot of art, that's why I think rich. People with money usually have a lot of art. Not a lot of money, I have no art!" (Jennifer, personal communication, February 5, 2016). Jennifer seems to have trouble answering the question, so I rephrase it to ask what types of art pop into her mind when she thinks of visual art. Immediately, she responds, "Paintings. I know there are others but that's the one that first pops into my mind. I don't know a lot about art" (Jennifer, personal communication, February 5, 2016).

George (science teacher 2) remarks, “The museums I’ve been to come to mind, like the Smithsonian in Washington, D. C. and the Museum of Natural Science here – I really enjoyed those. It’s not so much art, but more of displays of a wide variety of things” (personal communication, February 9, 2016). He goes on to describe some science and engineering aspects that he liked at those museums. George explains, “I really haven’t spent a lot of time where you have paintings and sculpture. So those things come to mind in terms of the classics – Michelangelo, the Sistine Chapel” (personal communication, February 9, 2016). I reiterate the question as far as what types of visual art comes to his mind and he says,

> I guess paintings would [come to mind] more than sculpture. Quite honestly, some paintings I wonder, why would anybody think that looks good? I’m not a big Picasso fan – is it Picasso the one who did those, the abstract stuff? Yes, the oddball stuff I’m not that much into. I’m more into realistic landscapes, and I love Western art – pencil drawings, pen drawings of Western scenery. And I guess some of the sculptures that depict broncos, cowboys, westerns – I really like that. (George, personal communication, February 9, 2016)

As George describes the Western-style art that he likes, he becomes more excited talking about art in general. He hones into his personal preferences and realizes that he has more art to discuss than he initially realized.

Ralph’s (science teacher 3) response has quite a few similarities with George’s statement. Ralph (personal communication, February 10, 2016) replies, “The classics I think – the paintings, photos, sculptures. I do like the moving types of art – the mechanics involved in that. There is some stuff that is art and I don’t really see how it’s

art; that's so abstract I've been told that I just don't get it." I ask if he visits art museums, and he says, "From time to time. I've been to the art museum here. I've been to the one in San Antonio. I think that's the one that has the felt painting of Spock from Star Trek – it was actually my favorite one there. I've been to a few other art museums" (Ralph, personal communication, February 10, 2016). I ask if he visits science museums. Ralph answers, "I've been to a few of those – the one here and the one in Philadelphia." He elaborates on the latter museum saying, "You don't look at the exhibit, but you mess with the exhibit" (Ralph, personal communication, February 10, 2016). This experience was in elementary school, but he says that he actually remembers some of the things there.

The art teachers recall their science experiences from school, and comment on enjoying the practical applications of science (labs and experiments) much more than the memorization and exams. They mention the mathematical route of certain sciences versus the natural sciences, and seem to prefer the latter. One art teacher also describes the type of thinking involved in science, saying that she was always accustomed to using the right side of her brain – the artistic side. This same teacher was the least intrigued by the sciences, but still asserts an appreciation of science teaching us how the world works. All of the art teachers tie into the sense of creation and discovery – something that they are very familiar with in the artistic realm – that is also promoted by the sciences. The science teachers claim to know little about art. They mention that art is outside of their realm, or that they do not understand a lot of it. All of the science teachers think of paintings when asked about visual art. Two of the teachers recall the classics, like Michelangelo's painting of the Sistine Chapel ceiling. One of the science teachers goes further in depth and describes specific types of western art that he likes. They also

mention having frequented science museums much more than art museums; and recall their interactive experiences at these museums. Interestingly, when asked about the sciences, the art teachers recall their experiences in school, while the science teachers do not. They think of art in relation to what they have seen socially or in museums. Both sets of teachers have some trouble discussing ideas of the others' subjects; however, as the conversations progressed, they were able to think of further mutual understandings.

Question 6 (Q6): Do you have an interest in the arts [sciences] or in learning more about the arts [sciences]? Please explain. Joanna (art teacher 1) explains,

> I think probably my favorite part of the sciences is biology, but I also have a background in massage therapy too. There we learned a lot about the science of the body and how things work. So I find that really interesting, more so than astronomy, for example. So I lean more toward human nature, psyche, anatomy – that's something that I've actually studied. I love science – it's good to understand who we are, where we come from, and how things work. (personal communication, March 3, 2016)

Joanna says that she is definitely interested in learning more about science; and that she just didn't pursue a degree in a science because it was hard.

With a similar response to Joanna's, Helen (art teacher 2) replies,

> My area would be in the natural sciences, more biology-related. I took biology in school and loved learning about DNA strands, how things work, how things grow, and how things happen. While I don't consider myself a scientist, I consider myself a curious person. I think, for me, I want to know about plants, growth, cycles, and things like that. I have even been involved in the decline of the

> monarch butterfly, so that's a special interest I have. (personal communication, March 1, 2016)

Helen is proud of the fact that she has been actively involved in the natural sciences with her monarch butterfly experiences.

Lisa's (art teacher 3) response is quite different from those of the previous art teachers. She states,

> I'm not seeking it [science] out. When I hear something on the news or in an article, I'm intrigued by it but it's nothing I'm seeking out. There are other things that I'd rather seek out than deal with that. I feel so bad – like I'm bashing on science. I have nothing against it, but I feel like there's an important role for science and I respect it. But I've never adapted or put myself into that role. I just don't have that side of my brain (personal communication, March 2, 2016).

Lisa seems to slightly regret her lack of interest in science, but makes sure to state her respect for the role of science in society.

In contrast, the following are the science teachers' perspectives on learning more about the arts. Jennifer (science teacher 1) reflects, "I would not be opposed to learning more about it [art]. As far as actually trying to be artistic myself, I don't really feel that I am and so that makes me anxious to try. But as far as learning more about it, I'm all about more knowledge, so that would interest me" (personal communication, February 5, 2016). I added, "So acquiring new knowledge, if it was in the realm of the arts, is something you would consider?" She says yes, and further explains her jealousy over her friends taking art history in college when she never did. Jennifer (personal communication, February 5, 2016) supplements, "So yes I would be interested in learning

more about it, but then as far as actually trying to do some art, I don't know. Having said that, I have done some of those go and paint with you friends. It was hard at first, but I've gone several times, so I think it's just that initial wall that's up." Jennifer sums up the feeling that many people have when they think about themselves attempting art practices.

George (science teacher 2) contemplates the question for a moment and then answers,

> I attended [a conference]; it had to do with STEAM – putting arts into science and that kind of a program. They talked about the different things with science, and they had different ways in which you could incorporate art into science. Those kinds of things I can see getting involved in and learning more about. We do some things in here [his classroom] with modeling and toy models; and I very much think that's very artistic the way those things can be rearranged. The 3D modeling – I like that aspect of it [art] and I'd like to learn more about that. (personal communication, February 9, 2016)

George mentions the incorporation of art into science as an aspect he wants to learn more about. This is a promising perspective for an art and science partnership in school.

Ralph (science teacher 3) responds similarly to Jennifer, in a straightforward manner, saying:

> Not so much only because I'm artistically challenged. My mother's an artist and my daughter's a blossoming artist. She can do much more than I can do and she's only in the 5th grade. While I aesthetically appreciate it, it's not my genre unless it's food – I'm a culinary master. I've never shied away from the historical

> perspective of it [art] or certain techniques or applications of it. (personal communication, February 10, 2016)

He agrees that the accumulation of more general artistic knowledge is of interest to him.

Two of the three art teachers mention a love for biology and anatomy. They have a natural curiosity regarding how plants grow and how the body works, so they have an interest in learning more. One of these two art teachers comments that a full science degree would have been too hard. The third art teacher says that while she may be intrigued by a scientific concept, she does not actively seek out more information. The science teachers are all in favor of learning general artistic knowledge or concepts. They are more interested in how the arts can relate to the sciences, or certain applications of the arts. Two of the three science teachers comment that they are in favor of acquiring general knowledge rather than trying to be an artist because they lack that artistic ability. Both groups of teachers share an interest in acquiring more knowledge of each other's subjects. At the same time, they share some anxiety or intimidation from certain aspects of the subject matter.

Art and Science Commonalities and Integration

Question 7 (Q7): Do you believe that art and science have commonalities? If so, what kinds of commonalities? When thinking of commonalities, Joanna (art teacher 1) mentions process and media, or method and types of materials respectively. Concerning process, she explains,

> I think the process is quite similar. If you think of coming up with an idea that you're testing in science, it's very much like creating a sketch in art

> where you study and develop a little bit. That process is very much the same: you're testing the waters, seeing how it's going – after you get the sketch, you're like okay I need these parts and you try and work through a finished product. So the whole idea of a hypothesis and coming up with a theory [is common with art and science] (personal communication, March 3, 2016).

Joanna's answer paints a nice picture of the thinking processes and practices of both art and science. As far as media, Joanna (personal communication, March 3, 2016) elaborates,

> I think just understanding your material, your medium, what you're working with – that could correlate with science, so you can get the most out of your material. In sculpture, using plaster and things with chemical reactions; knowing what's going to last and be archival – that you kind of have to test beforehand. A lot of professional artists fall in love with a material and become a master of that material. So you have to learn the anatomy of it – how it works, how it's structured, and so on. I think of Andy Goldsworthy and how he goes out into nature. He has to understand his media and that it will pass with time. So that's part of science too: understanding the resources that we have and how they work.

Joanna mentions the understanding of materials as vital to art and science. I have thought about media in relation to art, but she helps me to contemplate materials use in science as well.

When asked about commonalities between art and science, Helen (art teacher 2) says that she's never really thought about it. She believes that creativity, problem solving, process and categories are common traits of both disciplines. Helen (personal communication, March 1, 2016) responds,

> Science has a process and I can say art has a process. Science has different categories and I can say art has different categories. I will say that there is a level of creativity to science in many ways. I know that a lot of physics is theoretical and takes a lot of creative thought. Even in engineering, let's say when you're in school: Here's the perimeters of the problem, now solve the problem. In real life, it's like: this just happened, now what do we do?! So you have to be able to identify and construct and solve a problem which is a lot of right-brained thinking.

Helen (personal communication, March 1, 2016) explains more about the type of thinking in both art and science,

> Art is predominantly right-brained thinking, but there's also a lot of left-brained thinking, studying, and learning that goes on as well. Let's say I'm drawing a person: well, I have my kids [students] study the bones, the muscles, the way the body moves – so I'm integrating science. So, to say there's no creativity in science would be a mistake. I think the best scientist would be a creative one, one capable of thinking outside the box. I would also say science is problem solving, and that's a huge part of the visual arts. It's framing a problem and creating divergent solutions to that problem.

Helen's responses of creativity and problem solving sum up two very strong commonalities between art and science.

Lisa (art teacher 3) also mentions the type of thinking required by both disciplines, as well as research and craft (which incorporates process and media). She believes that art and science do have commonalities, saying,

> I feel like in both sides there's research. In art, you can research an artist, a movement, a technique – a way to break something down. I feel like that's really associated with science – you know, there's always a break down, like an equation, a different meaning, or a higher meaning. So that research and break down, and how it's been created or adapted [is a commonality] (personal communication, March 2, 2016).

She continues to explain craft and incorporates creativity into her response:

> Precision in knowing your craft is important. In science, knowing a chemical equation and reaction and, in art, learning the craft [material] – something that works versus something that doesn't work. You need both sides of the brain for both [art and science]. For art, you need the creativity side that really focuses on pushing the limits; but you still need that practical side – all the things that you would learn from science, how things would need to add up. For science, you still need that creativity side that pushes us (personal communication, March 2, 2016).

Lisa (personal communication, March 2, 2016) concludes by saying, "You need a balance or connection of the two."

The science teachers also believe that art and science have commonalities. Jennifer (science teacher 1) replies,

> I think they absolutely do, and probably way more than I even recognize. The first thing that comes to mind is engineering and manufacturing – you have to come up with a design, which is scientific yet, artistic. Design and any kind of engineering – when you're going to be creating something to make, you've got to have that visual in your head, which then you have to transfer, which is a lot of what art does too. (personal communication, February 5, 2016)

She then mentions the connection of art to specific science classes:

> In biology, in physics I really can imagine how they connect, and in chemistry I imagine there's a lot of ways they connect. Physics is the one that I see it [the connection] as more direct, without having to find the correlation, as far as sciences go. Forensics – I can see there'd be a lot of direct connect. Just last week they were doing blood spatters, where they run down the classroom with dripping "blood" or they jump in the air with dripping "blood" and have it land on butcher paper, see how it lands, and then analyze it based on that. So that can, I feel, very easily be worked into art (personal communication, February 5, 2016).

I ask Jennifer why she can really imagine the connection between art and physics, and she says, "I feel like that's more in the engineering realm of science. Physics has a lot of pictures to teach the kids – diagrams that you have to draw and label. Not that the other sciences couldn't overlap with art, just that my mind sees it more there" (personal communication, February 5, 2016). Similar to Joanna's and Helen's thoughts about

anatomy and art, Jennifer mentions an exhibit that she saw showing the inner structure of the human body incorporating different movements. She states, "That's definitely art and science – creative minds came up with that idea." Jennifer even begins to think of chemistry [her content area] and how to relate artistic concepts. She adds, "Any concept I feel like you can make relate, if you're creative enough – like when we do bonding we draw pictures, and there are 3D images that the molecules make that could become art." Jennifer reflects on her students creating visuals: "To me, we're just doing quick sketches, but then I see it in my kids. There's so many of my kids that have that about them, where they're just so artistic – they want to make it fancy and they want to keep going." She then brainstorms another example of chemistry and art regarding the Periodic Table; and says that she can look through her syllabus and come up with more ways of incorporating art. She comments, "If you gave me a topic and said figure out a way that art could apply or that we could bring in art, I feel like I can make that happen. I feel like my team is pretty good at that – give us something we need to do and we can come up with something, even if it's not there yet" (personal communication, February 5, 2016).

George (science teacher 2) believes there is "very definitely a commonality" in terms of the artistic aspect. He reflects,

> If you can see the artistic value in science – think about evolution and how the different organisms transformed from one into another over millions and billions of years – and you can see this with molecules, how they fit together. If you look at a research aspect – what comes to mind is the DNA molecule and the different

> spiraling effects that has to do with that. I've seen hard models of those and, to me, that's art. (personal communication, February 9, 2016)

I added, "So do you mean that the commonality would be the artistic nature of science – the beauty or aesthetics?" He replies,

> Yes, along with the visual and just seeing what takes place in terms of points-of-view. I think that's one way that art can help us to view molecules, to look at the different viewpoints. And, of course, with paintings you have chemicals. So I'm interested in the chemical aspect of the paints and what they can do to get the different colors (George, personal communication, February 9, 2016).

George also mentions that they [chemistry teachers] can incorporate a lot about painting into what they teach because of the chemical compositions and the history of paint development.

Ralph (science teacher 3) also believes there are commonalities between art and science, commenting,

> There are a lot of commonalities – anyone who questions that should look at da Vinci for starters. In terms of thought process, real art is all about the expansion of what already exists, thinking creative, and pushing the boundaries; and science is very much the same way. We're not trying to reinvent stuff that we already know, but to think creatively and to apply in contexts that have never been thought of before or for new theories that have never gone before. (personal communication, February 10, 2016)

He says that subjectivity is definitely a commonality between art and science. Ralph (personal communication, February 10, 2016) continues, "Science isn't meant to be so

subjective, but you always have that human factor involved." He also comments that creativity is a big factor, saying,

> Most of our labs aren't art projects, but it's: here's an objective that I want you [students] to get; here's the equipment; there are no instructions, but be creative in coming up with a way to make it work. That's actually a real challenge for a lot of them because they're like well what's the process? I say well you have to build on that. It's very similar, I suppose, to when you give a person a blank canvas and you give them paint and say okay paint something. The first question some say is what am I supposed to paint? The actual art part, for most of the stuff we do in physics, you literally do need to have things drawn out pictorially to actually visualize what is going on. It's mostly through that thought process – that problem solving process (Ralph, personal communication, February 10, 2016).

Both the art teachers and the science teachers believe that art and science have commonalities. Each teacher mentions quite a few aspects that they relate to both subjects, from thinking processes to practical applications. All of the teachers think about what they currently do in their classes, and further connections that can be made. This is very promising for considering joint curriculum ideas.

Question 8 (Q8): What do you think about the integration of art and science? Integration or specialization of these two subjects? Joanna (art teacher 1) responds, "It's interesting because I wouldn't say I've ever been exposed to them taught together. But I can think of times, for me, putting art into something really helped me to understand it better. I feel like when you're using art, you're using all of these parts of your brain" (personal communication, March 3, 2016). She explains, "For example,

when you actually build a 3D replica of an atom, you're more likely to remember that just reading boxes from a chart. So I think there's something to the process of making things that helps a person learn/understand them." Joanna (personal communication, March 3, 2016) reflects for a short time and continues, "I can see how it can benefit both sides if there was an integration. I think in elementary school they do this more, but in high school we're just so stubborn! So I think there's something there – I've just never been exposed, which I think is kind of sad. I mean nothing in our life is kept compartmentalized."

Helen (art teacher 2) seems to think of the logistics of integrating the two subjects. She states, "I don't favor isolation, necessarily, but I wonder: how would it work? I think anytime you can involve an activity – experiencing something beyond just lecture and writing, I think is much more effective. So I'm not opposed to integration; I just haven't been able to figure out how it would look for the teachers" (personal communication, March 1, 2016).

Lisa (art teacher 3) has similar thoughts to Helen as to how the integration would work. She remarks that she is open to integration but would need more information on the matter. Lisa (personal communication, March 2, 2016) answers, "I honestly don't know how they'd be integrated. How would science benefit from art, from what we do here? I'm totally open to it [integration] but where's the front door, where do you access that? I feel like the art side would be more open to it than the science side." I ask her to expand on that last sentence, and she replies,

> I feel like art is more open and willing to interpret things in different ways. I feel like the science side is more rigid and that they probably wouldn't want to bring

> in the fluffy stuff. They'd probably wonder how that would actually benefit science. They would have to see a result from that experiment. But you never know, it just depends on the person too, and who's willing to teach it (personal communication, March 2, 2016).

Lisa believes that the art side will be more open to the idea than the science side, but the responses from the science teachers prove otherwise.

Jennifer (science teacher 1), one of the chemistry teachers and the science department chair comments,

> I think it could probably make it more fun to integrate them. We're so compartmentalized – even within science we're so separated, like biology versus chemistry versus physics. I think it'd be great; I would not be opposed to it. I would need guidance on how to do it, and some brainstorm ideas to get me started, but I think it would be a good thing. (personal communication, February 5, 2016)

Similar to Joanna's (art teacher 1) response, Jennifer talks about integration at the elementary school level versus the high school level. She says, "I feel like our elementary teachers do a great job of things that we always wish we could do or know we should do better. When I get my daughter's stuff from 5th grade, she has a lot of drawings – it's draw whatever you think about when you think of this topic" (Jennifer, personal communication, February 5, 2016). Jennifer says that in elementary school students are free to do this, but in high school we're so regimented. She describes a unit where her daughter learned about space; and the art teacher decorated the hallways with space cowboys and astronauts that the students created. She reflects, "So I feel like it's

already happening at some places – this connection between art and science – just maybe not so much at the high school level" (Jennifer, personal communication, February 5, 2016).

George (science teacher 2) describes incorporating common units into the individual courses. He responds, "I think that you can incorporate both in the individual courses. I think you need to have, for example, a chemistry program and an art program and then you can have common units. The courses don't need to be kept entirely separate" (George, personal communication, February 9, 2016).

Ralph (science teacher 3) thinks about the application process when responding about integration. He states,

> I believe it can be a good thing – it all comes down to how you apply it. If you can expand on the thought process, that would be a good thing. I think the art would be the same way – if we're incorporating it for the warm and fuzzy, that would be a detriment. But if we're actually bringing it in for focus and application of how the principles of science apply to the art or vice versa, to illustrate, then that's an awesome thing, in all honesty (Ralph, personal communication, February 10, 2016).

Ralph seems to respect both disciplines and points out the importance of integration to enhance, rather than weaken, each discipline.

Together the art teachers and the science teachers are in favor of integration of art and science. One art and one science teacher give similar responses when considering that this integration occurs more in elementary school than high school. They mention the rigidity of high school curricula, which goes along with the logistical concerns that all

of the teachers have. It is interesting that even though the teachers are being interviewed separately, their answers have similar patterns. They have a mutual concern for the promotion of integration without detriment to either subject.

Question 9 (Q9): Do you integrate art/artistic concepts into any of your science lessons? [Do you integrate science/scientific concepts into any of your art lessons?] If yes, what kind of concepts and how? If no, would you consider doing so, why or why not? Joanna (art teacher 1) replies,

> I think I could definitely do a better job, of course. Being that I work with ceramics and sculpture, it comes up very often. I try to help the kids understand – when this clay heats up, it's actually transforming. I do have some projects where they have to go out in nature, scavenge, and find [materials] – so, understanding their environment a little bit. We do a lot of anatomy – from the muscles to the bones – when we're trying to understand proportion. I feel like there's definitely more there that can be developed, and they [students] eat it up and feel smarter. (personal communication, March 3, 2016)

Joanna says that she is definitely open to including more scientific concepts in her lessons.

Helen (art teacher 2) says that she would absolutely consider it as well. She elaborates,

> We teach color theory and I think that does touch on science because we talk about the prism and the eye – rods and cones – and how we see and how light is different from paint. We talk about the anatomy and physiology of the body and how it moves. I think we can also consider perspective as a part of science –

> atmospheric perspective and how things recede in space. In painting, I like to talk about how paint is made, what's the history, does it have a binder – it used to be egg tempera or rabbit oil. Even the process of the fresco and mixing the plaster layers – to me, that touches on science. I think there's integration going on somewhat without recognition (Helen, personal communication, March 1, 2016).

Lisa (art teacher 3) describes the process of experimenting with paint as relating to science. She says, "I feel like it is science – adding things to paint is a type of experiment, to see how the paint reacts. Also, maybe clay going through the kiln process is a transformation" (Lisa, personal communication, March 2, 2016). Lisa reflects, "I don't know how I'd add science into it [art]. Maybe there's another side of it that I incorporate and I don't even know about. Maybe I haven't accessed that part of it and if I did, I'd be more aware." She says that she's open to learning more scientific concepts because when her students ask her questions, she wouldn't have to respond with "ask your science teachers" (Lisa, personal communication, March 2, 2016).

I asked the science teachers about the incorporation of art into any of their lessons. Jennifer (science teacher 1) replies, "So since I've been teaching chemistry, I'm going to say not so much other than the sketches that we do with the kids to get a visual representation of what I'm explaining – the bonding, the atoms, molecules, how they hook up together, and the shape of the molecule – we draw those" (personal communication, February 5, 2016). She mentions that when she taught IPC (integrated physics and chemistry), they incorporated a lot of sketches for word problems. Jennifer says that she would be willing to try integrating more artistic concepts into her science lessons.

George (science teacher 2) reflects on the question for a moment and then responds,

> I don't incorporate specific aspects of art. We look at crystal structure, for example, and there are seven different shapes for crystals. I can certainly see that being approached at a more artistic level of how they look and how they combine together. But it's not something I specifically say: here's my art part of the program. Quite honestly, I don't know if I have enough artistic knowledge to bring something like that into the program. I wish I were more knowledgeable. (personal communication, February 9, 2016)

He continues by mentioning examples of art and science that he's seen on television: using x-rays on paintings, using chemistry to preserve paintings, Leonardo da Vinci's notebooks, using origami to create molecules, and using magnets with iron filings to create unique patterns. George loves all of this and would like to incorporate more artistic concepts into his lessons (personal communication, February 9, 2016).

Ralph (science teacher 3) comments, "I try to apply it where I can. For example, light and color is an easy one." He mentions the drawing of diagrams: "We don't do so much on the artistic level, but I do find that if kids incorporate coloration, it helps them keep track of what is what. I have noticed that when kids have an artistic tendency or interest, if you can apply that to their interests, they're more interested in the physics" (Ralph, personal communication, February 10, 2016).

Again, both the art teachers and the science teachers have more similarities that differences in their responses. While the art teachers do not integrate specific science concepts into their lessons, they are aware that aspects of their lessons are science related;

and they would like to learn more about the science and how to share this with students. The science teachers do not integrate specific art concepts into their lessons, but they say that they try to incorporate art where they can. They also want to become more knowledgeable, in order to promote art with their students.

Art and Science Concepts and Curriculum

Question 10 (Q10): Do you believe students would benefit from learning artistic and scientific concepts together? Why or why not? Joanna (art teacher 1) answers, "Yes, I do. I think it has to do with art activating a lot of your brain so you learn a lot when you're creating. So I think integration would be awesome – instead of studying a book, you're creating a book of your knowledge, your drawings, and so on. You put a piece of yourself into it and that helps your understanding too." These are Joanna's thoughts regarding art's influence on science. Concerning science's impact on art, she says, "I think having the science component would really elevate the arts by bringing a level of genuineness; bringing it to a higher level for both sides" (Joanna, personal communication, March 3, 2016).

Helen (art teacher 2) replies, "I think they do in some ways already. If you take all the research that's been done, for example: students in band learning music, counting, and rhythm, which are really mathematical, tend to do better in math subjects. So I'm sure there must be more that I don't know about." I ask her if she thinks students would benefit from learning more of these concepts together, and she comments, "Absolutely. Another level is how do we learn and remember things – if you just study something and

recite it that's one level, but if you've experienced or molded or constructed it, it's remembered on multiple levels" (Helen, personal communication, March 1, 2016).

Lisa (art teacher 3) reflects on increased understanding for students. She says, "I do, I feel like that would help a student like me who understands art more. It could help me to understand something from the science side by integrating something that I do understand and putting it on that level" (Lisa, personal communication, March 2, 2016). Lisa also feels the same would be true for a science person – integrating a science concept into art would broaden their understanding of the arts.

Jennifer (science teacher 1) thinks of more specific topics that can be covered by connecting science and art. She states,

> I think there are definitely topics where it would be very beneficial. Instead of just learning about color in art, you could learn about color in art and science. I feel like there could be a lot of bridging with that concept. With light – I know in physics we talk about light and even in chemistry we talk about light, colors of light, and wavelengths of light. I feel like that could be a great place to connect. I believe there are a lot of things in art and science that we [teachers] can communicate about and help each other with. So I do feel like it would be great for the kids if they were getting it from both sides and seeing the connections (Jennifer, personal communication, February 5, 2016).

Intriguingly, Jennifer pinpoints one of my ideas for the potential ASK curriculum – art and science teachers instructing students on common concepts; and helping them to see the connections between the two subjects.

George (science teacher 2) responds in a similar fashion to Jennifer. He candidly says,

> If it's a unit program, I think that the kids could certainly benefit from that. Now obviously, there are kids who are right-brained/left-brained, that kind of thing. It would be great if there were a program that blended the two together or would blend the two together that kids would have options for. I would like to see the kids have more options as to what they can take. Just like not every kid is destined to be an art major, not every kid is destined to be a chemistry major. I see some kids who have some interest in both, and they can see the beauty of art, the technical aspect of art, and the chemistry behind art (George, personal communication, February 9, 2016).

Remarkably, George's answer hones in on another of my reasons for an ASK curriculum – to give students with dual art and science interests more options for classes to take while in high school.

Ralph (science teacher 3) mentions the types of students and the benefit of breaking down barriers by connecting art and science. He responds,

> I would, specifically for the art-centric student, because when they come across more of that mathematical or scientific concept, a lot of times they self-stereotype and say: that's not my area; I'm more of an artist and so I'm giving myself an excuse not to try very hard or to apply this, so I'm setting up a little barrier. This [connecting the concepts] would help to break down that barrier. And at the same token, you have those people who say: I'm very analytical; I'm not very artistic. If we're applying, at least, to the creativity aspect of it – you don't have to be a

> Picasso, but if you can just think outside the box more and be a bit more creative, applying what you know in a new context, then you're gaining so much more (Ralph, personal communication, February 10, 2016).

I add, "So do you think it would be a benefit to bring those concepts together to show students how to think a little differently?" He answers, "Absolutely, if everything is connected in some way, then somewhere along the way for them to see that, they have to be taught and shown the connections. All too often, we keep it segmented and say: when they graduate, they'll figure it out" (Ralph, personal communication, February 10, 2016). Ralph reiterates that everything is connected and we need a balance in school.

Both the art teachers and the science teachers feel that students would benefit from learning artistic and scientific concepts together. The art teachers mention the benefit of creating artworks to promote higher-level thinking and understanding of science. In turn, the science brings a higher purpose to the art. The science teachers comment on the connection making and the bridging of concepts. They mention the need of options for the students, so those who have mutual interests in both subjects have a way of experiencing them together. One science teacher points out the need to break down the barriers between and misunderstandings of each subject – all very encouraging points to the possible future collaborations of art and science in the high school setting.

Question 11 (Q11): Would a curriculum that focuses on integrating art and science be feasible in the high school setting? Please explain. Joanna (art teacher 1) thinks of the logistics and replies,

> I do, I really do, but I think it's an interesting legislative issue. What is that course, how do you implement it, and how do you check that it's being

> implemented? In that instance, I think the best thing to do is educate the educators – give them hands-on tools, give them things they can start to use, start getting the word out to them, show them successful ways that it's working, and then they would buy into it. (personal communication, March 3, 2016)

Joanna brings up some great points about educating the educators and showing them how to implement such a curriculum.

Helen (art teacher 2) responds similarly, saying, "I think it could be – there would probably need to be a pilot. I think you could meet with some scoffing initially, but there would have to be proof. Maybe you take a hard case and show me that it works – I think if more of their [students] senses are engaged, more learning is retained" (personal communication, March 1, 2016).

Lisa (art teacher 3) says, "I think high school would be a good level. I think that a lot of students fall between – they think they're good at the craft in art or: oh, I was never good at art; I'm good at science. It kind of gives them that in between place – a place to see the connection between the two" (personal communication, March 2, 2016).

Jennifer (science teacher 1) answers, "Yes, yes. I feel like we've already incorporated so many classes on the technology side, like the engineering and digital graphics classes. To me, that's a scientist wanting to be artsy. I feel like we can definitely incorporate more of that." I add, "So if there was a class that was particularly art and science, would it be feasible because it's kind of already being done?" She replies, "Yes, I feel like there would be a group of kids who would think: oh yeah that's awesome; I like science and I like art. I feel like that would be great" (Jennifer, personal communication, February 5, 2016).

George (science teacher 2) thinks about the content and length of the curriculum and states,

> Yes. I don't have enough knowledge in terms of can it be a full year course, but certainly a semester course. If you incorporate the different sciences; if you have somebody who's knowledgeable enough in all those areas, it's certainly a possibility. Maybe something almost like team teach, where you have a teacher to come in and do lessons on the biology, the physics, the chemistry – basically, a guest lecturer who would come in and talk about different aspects that might be a possibility. (personal communication, February 9, 2016)

George gives me some valid points to consider regarding the teaching aspect of the curriculum.

Ralph (science teacher 3) also mentions the teacher(s) involved, saying, "Yes, it would be absolutely feasible. It wouldn't be easy at first – you'd have to have the right teachers to do it. Very often when we do integrations, there's resistance when merging traditional curricula. So you'd have to be creative in blending these things in" (personal communication, February 10, 2016).

It is encouraging that both the art teachers and the science teachers feel that an ASK curriculum is feasible in the high school setting. It is also intriguing that the art teachers, not the science teachers, are the ones who mention the need for a pilot as an experiment – a way to test the curriculum and its results. All of the teachers discuss logistical issues such as implementation, and one of the science teachers starts brainstorming ideas for this. One art teacher and one science teacher comment that there

may be resistance at first, but creativity and proof of effectiveness will be important for the success of this type of integration.

Question 12 (Q12): Would you be willing to collaborate with other science and art teachers to help develop ideas for such a curriculum? Joanna (art teacher 1) enthusiastically says, "Yes, I love collaborating, it's awesome. I don't care who I'm collaborating with – there are wonderful things out there and I love coming up with ideas. I'm not tied to tradition – I always want to make things better, so yes I'd be totally willing!" (personal communication, March 3, 2016).

Helen (art teacher 2) says, "Sure – I think you'd want them [the teachers] together, because we're kind of over here and they're kind of over there [on opposite sides of the school]. I think it would mainly be: what are your ideas, what do you think could fit, and then figuring out how we could meet them." She explains further,

> I don't know how to meet them [the science teachers]. I would need their suggestions and then I can come up with the projects. From a science point-of-view, what are the concepts that they have a really hard time with; are there any structures in that concept; could we build models; could we sketch; how could I approach that in a way that's practical and useful to the science person (Helen, personal communication, March 1, 2016).

It is interesting that Helen considers the science teachers more than herself in this response. She wonders how she can assist the science teachers, not how they can assist her.

Lisa (art teacher 3) helps me see many aspects of the process and comments,

> Yes I would. Just so I could get a better understanding – it would be nice to see that other side, not knowing much about it – to be able to collaborate. Also to work with other art teachers to see their points-of-view on how well we could integrate the two. Once hearing the feedback from both sides, I'd want to absorb it and then understand how can we actually do this. I feel like I would need to educate myself on the science part; I feel like that's where I'm lacking. But if I had the opportunity to sit with scientists and get the brainstorming, that would help create the structure. And, vice versa, having them educate themselves on the art aspect so there's an understanding – so it's not just hitting heads on this side or that, but actually seeing the incorporation of the two [art and science]. I would think the brainstorming would have to happen before the structure, because it sets the skeleton and you can build all the other stuff from there. (personal communication, March 2, 2016)

Remarkably, Lisa provides the most in-depth answer of the art teachers, even though she has been the least intrigued by science.

From the science side, Jennifer (science teacher 1) states, "Yes, that's stuff I'm good at. If I know your [art] topics and my topics or a new topic that neither one of us do, I'm good at coming up with a plan. I feel like a lot of the science people would be good at that, they just need to sit down and talk about it" (personal communication, February 5, 2016).

George (science teacher 2) gives a similar response, saying, "I don't know that I'm a good idea person. I don't initiate ideas, but once a topic is out there, that's

something I can get a hold of. I don't have a problem with that at all; I would enjoy that I think" (personal communication, February 9, 2016).

Ralph (science teacher 3) seems to think of expanding the ideas to more art and science teachers once the initial ideas are laid out. He says, "Yes, yes I would. You could expand on that more if you already had it nicely laid out; because you'd have the person who says: I'd be willing to do this but I'm not a science teacher, or I don't know much about art, or I don't see the connection. So it'd be good if you had that kind of laid out" (Ralph, personal communication, February 10, 2016). He then continues to actually brainstorm some ideas for the potential curriculum, which is exciting and promising.

All of the teachers comment that they are willing to collaborate with each other. While one of the art teachers expresses her love of brainstorming ideas, the other art and science teachers mention learning about each other's topics/concepts first, and then coming up with a plan to implement. They are all positive and open-minded when considering this collaboration and the results that may come from it.

Scientific Art Image Conversations

As previously mentioned, these follow-up discussions centered on eight images of scientific art that I showed each teacher individually. I explained that these images were categorized as scientific art; and I asked each participant to share her/his thoughts about the individual images. For the initial responses, each teacher had no previous knowledge of the images and had no indication of what each image depicted. I then gave a description, in the artist's own words, of what each image explored; and asked the teacher to share any further perspective on what they were viewing. In this section, I have

presented a smaller version of each image, as well as the verbatim responses of each participant and the artist statement. These conversations developed naturally, without following any type of script or premeditated questions.

Image 1: *Skyline in the Snow*.

In response to Image 1, Joanna, art teacher 1, eagerly asks, "So it's science art? I feel like I'm looking at a cross-section of frozen crystals or something – from a science standpoint. But from an art standpoint, I see a monochromatic color scheme, value, contrast, line, texture, and pattern. Well, there's, kind of like, buildings; I really feel like it's crystal or ice something." [I then read the artist's description aloud: "This image was made by accident when a mixture of particles in a salt solution dried. The straight lines and angles [are] because of the crystal structure of salt when it dries. The original image was taken in black and white with a light microscope – color added in image" (Zhushma, 2015). This image reminded the scientist/artist of the New York City skyscrapers peeking through a hazy blizzard of snow falling on the city (Zhushma, 2015).] Joanna responds, "Oh that's cool! Well, we use salt with watercolors [in art], so now I can tell them [students] salt is a crystal! Before I just told kids that salt absorbs the water and it's beautiful [laughs]." Joanna says that she can definitely see this image as scientific art,

especially when the artist added the color to it. She adds that some color theory plays into this image as well because, for example, if it were red it would relay a completely different feeling. Joanna also remarks, "Yay, that was fun!" (personal communication, March 4, 2016).

Helen, art teacher 2, explains, "[She sees] some kind of crystals. It's monochromatic; it's kind of cool. I mean you could interpret it as some kind of buildings or structures in space." [I then read the artist's words and Helen loves the title.] "I like the blue – it's nice and makes it more atmospheric." [The explanation does not really change her perspective of the image.] She continues, "To me, it's something that has some kind of structure behind it but it's still cool. It's naturally occurring in some way – that's the science part; it's cool to me as an image an artist can create. It has visual merit." Helen believes that the image is rightly classified as scientific art, and says, "Yes! We've got great contrast, texture, interesting positive and negative space, and repetition with variation. [There's] a lot you could say about it" (personal communication, March 2, 2016).

Lisa, art teacher 3, comments, "The first thing I thought was crystals, because of the pointiness of the tops here [points to the elongated blue shapes]. Then in between the darker sections [it] looks like ice, like cracks." She also describes her thoughts about a palette knife streaking paint across a page. A palette knife is an artist's tool that is a flat piece of metal, wood, or plastic with a handle; it is used to mix paint and apply it in thick layers to a canvas. Lisa adds, "It almost looks like a print [printmaking], because there's parts that didn't come through as intense as the other parts." Printmaking is an art process in which ink or paint is applied to a carved surface; and then paper is pressed to

this surface, thus duplicating the image. [I then read the artist's description aloud.] She says, "Oh cool, I like that." Lisa relays that she can see the image as scientific art, as well as notice the buildings after hearing the title "Skyline in the Snow" (personal communication, March 3, 2016).

Jennifer, science teacher 1, describes, "It's a lot of blue, different shades of blue. What comes to mind is the inside of a cave – it has stalagmites and stalactites that go from top to bottom and connect in the middle. Science!" [I then read the artist's description aloud.] She says, "I see the crystals, yes. I would have never known that's what it was." [I ask if she thinks it's artistic.] Jennifer replies, "Absolutely, because it looks really pretty. I mean it's just the lines and the shapes and the shades – to me, that's what art is" (personal communication, February 6, 2016).

George, science teacher 2, reports, "To me, it looks like crystal structure, ice crystals and how they intermesh. I like the colors." [I then read the artist's description aloud.] He says that he is "picturing some sci-fi movies where they have the spires on the buildings come up to points." George explains that there are thousands of salts out there and that this is how the salts dried, producing one of seven shapes of crystals. In reference to the title, he comments, "I like the idea of thinking of it as a skyline, but otherwise it looks exactly as what I thought it was going to be. I like it." He also mentions that students could try to come up with different synonyms and antonyms for the images (personal communication, February 10, 2016).

Ralph, science teacher 3, responds, "I'm going with stalactites and stalagmites or a crystal." [He pauses, trying to think of more to say.] "Okay," he says, "You could have the kids try to identify what that is as a warm-up type thing. Other than that, I have

no earthly clue. I'm seeing so many different things in this. From an artistic standpoint, it also looks like a cityscape." [I then recite the artist's description and ask if he can see this as scientific art.] Ralph answers, "Well, trying to figure out what it is from the contextual clues; I can see where you have that scientific part of explaining for analysis. You have the creative aspect of: what could this thing be? From an artistic standpoint: once we identify this, how could you make it look like this or [reproduce] it in some other application?" (personal communication, February 11, 2016).

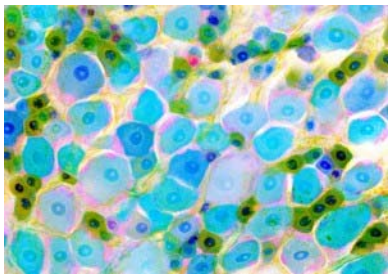

Image 2: *Easter Basket*.

In response to Image 2, Joanna (art teacher 1) says, "Okay, I definitely see cells of some sort. This reminds me of biology, but in art I see pattern, shape, contrast, analogous or split-compliment color scheme, and movement. My eye follows the green around the page [in] kind of a diagonal movement." [I then read the artists' statement aloud: "The dorsal root ganglion [in the spinal cord] contains sensory neurons that detect stimuli from the environment which then send these signals to the spinal cord and brain" (Taylor-Blake and Pearson, 2015). I further paraphrased their words to my participants, detailing that the green neurons contain a different gene than the others that are light blue and dark blue. This image was taken with a microscope as well.] Joanna reacts, "That's awesome;

that's my spinal cord – it's so pretty!" She immediately begins to brainstorm ideas with me, stating, "This would be so neat to start as a background [of a painting] and have the kids connect the cell idea to different parts of their personality, or different people in their lives who play unique roles; and then paint those on top of this cool [cell] background." We get very excited about these ideas. Joanna continues, "Or they think of themselves as layers and this [cells] is one layer; and they put another anatomy layer [on] until they get to their actual self-portrait – what they look like on the outside. That would be so cool for high school kids – to find the beauty in themselves" (personal communication, March 4, 2016).

Art teacher 2, Helen, reports, "Interesting. That makes me think of something that might have happened in a petri dish; like there's some multiplying going on." She describes artistic qualities like an analogous color scheme, which means colors that are similar to one another, like blues and greens. Helen continues, "From a formal artistic view, I like the color palette – it's kind of analogous with a little touch of pink. I like the variation of shapes with repetition: big to small, and some light with others dark; so there's a good sense of unity and repetition without being boring because of the variation." [I then read the artists' description and she loves the title; I ask if this changes her perspective in any way.] Helen replies, "It's utterly fascinating; it's cool and beautiful. To think that's something inside the body – you don't think of it as being art inside your body" (personal communication, March 2, 2016).

Lisa, art teacher 3, explains, "I think about: when working with paint and we do alcohol dissolve, it starts to push away the paint and separate it into little colonies of circular areas." Alcohol dissolve refers to rubbing alcohol dropped onto wet paint. It

produces the type of effect Lisa describes, which is very similar to Image 2. She adds, "But it also reminds me of Monet's *Waterlilies*, but more of a modern version of that. You see the green and that reminds me of a type of lily pad, the blue is like the water, and the pink shining through would be like the flowers." [I recite the artists' words and ask if this changes her perspective, now knowing what it is.] Lisa says, "Oh cool, nice. I mean I can definitely see the cells, but I still see what I see" (personal communication, March 3, 2016).

Science teacher 1, Jennifer, says, "This one, it's very colorful. They injected a little bit of dye, I believe, because it's not normally that colorful. I'm going for some cellular kinds of things, maybe an onion." [I then read the artists' description aloud.] Jennifer continues, "In my mind, I was trying harder to make scientific art." [I ask, "What do you mean?"] She responds, "Not just something that's natural, something that's made. This is natural and it looks cool, but I was imagining someone coming up with this" (personal communication, February 6, 2016).

George (science teacher 2) describes, "To me, that's a cell structure. I see they used different dyes; [and] you can see the nucleus, fat cells, cell structure, cell walls." [I then recite the artists' description aloud.] He replies, "The kids do something like this where they take the skin of an onion and they stain it and look under a microscope, so they can see the different patterns." George continues, "So [students] looking for patterns, commonality; what do you see in common in all these structures – that would be some artistic aspect of it" (personal communication, February 10, 2016).

Science teacher 3, Ralph, proclaims, "Oh that is such a biology cell group. I don't think I'm seeing cell walls; I going to venture and say it's skin cells?" [I read the artists'

description of the image.] He then explains that this image could be used for biology, where the "different dyes are how you identify what cells are which; [for chemistry] how do these chemicals bond; [and for art by] looking at pattern and using it also in science to identify different things" (personal communication, February 11, 2016).

Image 3: *Rainbow Bubbles*.

After studying Image 3, Joanna (art teacher 1) describes, "Okay, this is some kind of chemical or water – something that is reflecting light, which I think is awesome. So there's the whole refraction – I do talk about that!" [This comment jogs her memory and she mentions a 2-D, or drawing, lesson in her classes.] "In my classes, when I teach 2-D we talk about shading; I talk about light and how it bounces off of objects. I do that!" [She gets excited because she realizes that she teaches scientific concepts.] Joanna continues,

> This [Image 3] reminds me of that too, because I'm seeing the color spectrum and that's really neat. From an artist's standpoint, I'm wondering what the brown stuff is back behind [the bubbles]. I definitely see color, value, intensity; I think of a kaleidoscope; it makes me happy [and] it's just exciting – all those colors

working that way, in that sense. It's mainly blue so it gives a calm sense, but then you have all these vibrant reds and yellows that make it exciting.

[I then read the artists' description of the image: "In our current digital age we are surrounded by liquid crystals in places like our phone, our TVs, and our computer screens. These special molecules contain special light-bending characteristics that cause interesting rainbow patterns when viewed with polarized light" (Turner, Liffland, and Ashby, 2015).] Joanna remarks, "No way! That's really cool! This would be really cool in the digital graphics class. I'd want to tell [the teacher] to show them this, so they understand the screen they're staring at for all those hours" (personal communication, March 4, 2016).

Helen, art teacher 2, exclaims, "It's a bit trippy! Scientifically, I sense water droplets or something reflective. Artistically, it's like a version of a Jackson Pollack – a no focal point kind of painting; overall, more modern because it isn't asking you to look in any one place." She describes more artistic elements of the image, saying, "Rainbow color palette, repetition with variation, contrast; it's kind of like there should be a Where's Waldo, like you're trying to find a certain one – you look all over." [I recite the artists' statement.] Helen adds, "Wow, interesting; yes light-bending, it makes perfect sense" (personal communication, March 2, 2016).

Art teacher 3, Lisa, comments, "That reminds me of a kaleidoscope. It almost looks like there's water droplets too. Where the light hits the water droplet, it creates a prism in each of the droplets, which changes in between. I feel like [I'm] looking at water under a microscope." [I then read the artists' description of the image.] Lisa

relays, “I like it.” Thus far, Lisa is not very excited about or interested in learning what the images actually are (personal communication, March 3, 2016).

Jennifer, science teacher 1, responds, “Oh cool, bubbles, refraction – love it. This is more where my mind went – with the light, the physics, the reflection, refraction, diffraction, all of the above; and the colors of light that you get all from white light – love it.” [I then read the artists’ words.] Jennifer describes a bubble lab that her students do. They watch the swirling colors – the diffraction. She says that they do experiments like what is shown in the image, but that they just do not take pictures of it (personal communication, February 6, 2016).

Science teacher 2, George, conveys, “I see light shining through different things. I’m not sure what those things are – could be little pieces of glass, light from different angles, rainbow effects, ROY G BIV, colors, that’s what I see.” [ROY G BIV is an acronym for the colors of the rainbow, or visible spectrum.] George explains that he asks his students about colors, and they answer with ROY G BIV. He adds, “We get into where colors come from and how the electrons are involved in the process, absorbing energy and releasing energy.” [I recite the artists’ description of the image.] George explains that he is familiar with bubble technology for memory in computers. In physics, they look at the polarization of light; and he can see the “artistic nature with physics – light and color and rainbow art” (personal communication, February 10, 2016).

Ralph (science teacher 3) asks, “Is this light being refracted through a bunch of bubbles?” [I read the artists’ words about the image.] Ralph responds, “Oh very cool!” He describes that, in his AP Physics 2 class, they talk about polarized light. Ralph explains 3-D movies and 3-D glasses, and how they work. He is very good at explaining

these concepts and always applies it to something in the real world – he was actually teaching me with his responses. Ralph concludes, "From the scientific aspect you can go into the light colors; from the art aspect, how can you use polarized light in creating an art structure with a fluid or clear material" (personal communication, February 11, 2016).

Image 4: *Snowflake Robe*.

Art teacher 1, Joanna, ponders Image 4, "Hmm, this too is like some kind of cross-section. I feel like it's a sponge or some kind of microorganism of some sort – the way that it has a center and radiates out. Art-wise, I see radial design, value, shape, a background versus a foreground, and pattern." [I then read the artists' statement: "This fractal-like spot was seen with an electron microscope. Some material crystallized on the surface, like ice crystallizes on a window. The surface on which it lay had a wavy structure, giving it a flowing, robe/curtain-like, appearance" (Ina and Zhushma, 2014).] Joanna replies, "That's so cool; I mean when you look in the microscope, it is beautiful what you can see" (personal communication, March 4, 2016).

Helen, art teacher 2, contemplates, "Hmm, frost and fractals, very organic. It's beautiful – the patterns, the organic nature of the growth. You can see from the edges

[that] it's little bits and then they start to coalesce; and then they join and then branch. It's really, really beautiful – good contrast." [I then read the artists' statement.] Helen becomes more excited, saying, "Oh my gosh, yes the fractals – they're so beautiful and you can just zoom [in] and go on and on. I really like them a lot." She then reflects,

> It's interesting because, as you're showing me these images, I didn't even know they existed. Here are all these science images that are so cool, why not show them to kids; why not teach them art vocabulary and art speak directly relating to this scientific stuff; and the same thing, for us to be able to appreciate [science] which I love, I absolutely love. I don't mean to bring religion into this, but I think God is the ultimate creator; it's so amazing – who would know you could look under a microscope and see that? (personal communication, March 2, 2016)

This is an exciting reflection on Helen's part. She has changed her perspective of art and science partnerships since the pilot study. Helen was skeptical at first but, after multiple discussions of art and science, she is now enthusiastic about the collaborative possibilities.

Lisa (art teacher 3) comments, "It reminds me of snowflakes. The blue and the white – I feel like if you're underneath a frozen lake and if you were looking up at the ice, the bright part here [points to the center of the image] would be like the moon projecting through the ice crystals." From an artistic standpoint, she states, "As art, it's monochromatic; the scheme flows well. There's a change in size, which causes your eye to look around the image. Yes, I would totally see it as art too." [I then read the artists' statement.] Lisa says, "Nice, I like that." She does not add any more thoughts (personal communication, March 3, 2016).

Science teacher 1, Jennifer, responds, “Snowflakes that aren’t snowflakes, I’m guessing; crystallization, crystals, something dried?” [I read the artists’ explanation of the image.] She explains that it probably looked like a flat surface until you look at it under a microscope, and then you see the waviness (personal communication, February 6, 2016).

George, science teacher 2, describes, “Snowflakes. Crystal formation. You see this in the wintertime when you have frost on your windshield. It could be a delta formation, in terms of geography; a delta formation coming up from rivers. To me, that’s crystal formation.” [I recite the artists’ statement.] He replies, “Yes! Almost like a set of drapes/shower curtain – I see the undulating patterns there.” In terms of artistic nature, George comments, “Look at it and see if you can find any two patterns alike. There are no two snowflakes alike, so you’re seeing that aspect of that – I like that. I can see it as a wallpaper because of the patterns” (personal communication, February 10, 2016).

Ralph (science teacher 3) exclaims, “Wow, that looks like a snowstorm. It’s too leafy – is this some sort of algae?” [I start to read the artists’ statement, and when I say it’s seen with an electron microscope, he says “Oh, wow!” with enthusiasm.] He adds, “I can definitely see the application of what an electron microscope does and what you can see from it. From an art standpoint, you could probably work with applying how you could use different textured materials to roll over onto something to make a type of image” (personal communication, February 11, 2016).

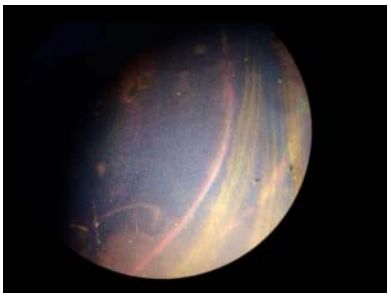

Image 5: *Nano World*.

As she examines Image 5, Joanna (art teacher 1), states, "That looks like a planet – something you would look at through a telescope. In art, I like this idea of talking about light and how it affects color. I don't know what the pinks and the yellows spinning around the planet are but it'd be interesting to find out." [I ask if it would surprise her to discover that it's not a planet, and I then read the artists' statement: "As viewed through a confocal microscope, this world was crafted from a transparent polymer, and is covered by small tree-like structures. These tree structures interact with the light and only reflect the color that you see" (Tippets, Fu, and Lopez, 2014).] Joanna reacts, "No way! That's really neat. Sometimes we set up colored lights on the kids to look at what's reflected and what you see – that [image] would be a cool tie-in" (personal communication, March 4, 2016).

Art teacher 2, Helen, comments, "Pink Floyd [she laughs]. Yes, obviously a planet – I think, I'm not sure – maybe a marble, but it's really cool. [It] has nice analogous coloration, good contrast, nice mood – very mysterious." [I read the artists' explanation of the image.] Helen continues, "It strikes as a planet, but I was like hmm [makes her wonder]. In that sense, it's very creative because they've taken one thing and given us the impression of another" (personal communication, March 2, 2016).

Lisa, art teacher 3, explains, "[It] reminds me of a planet, almost like Saturn without its ring; or maybe the moon – looking through a telescope during an eclipse or something. That's all I see with it." [I then read the artists' statement.] Lisa adds, "I think it can be artistic, but I still see the scientific side more. Artistic [aspect] being creating something like that – the process, that's a big part of it" (personal communication, March 3, 2016).

From a science perspective, Jennifer (science teacher 1), remarks, "Well, [it is] one of the planets or a moon. I'm not really sure which planet it would be. [It's] pretty; has lots of color – based on gases I'm guessing?" [I then read the artists' statement, saying it's actually Nano.] Jennifer answers, "It looks like a planet to me. It'd be interesting to relate an image from the macroscopic to the microscopic and see why they look similar" (personal communication, February 6, 2016).

Science teacher 2, George, reflects, "When I taught astronomy we looked at the different planets – I think they're beautiful. I very much think this [image] is artistic because the solar system goes back to Galileo, when they started looking through telescopes and seeing the difference between stars and planets. I like it." [I ask George if it would surprise him if it were not actually a planet; I read the artists' description of the image.] He responds, "Yes, it would. Any time you see a color, it's always reflected – you never see what's being absorbed. It makes you think of a planet and, if that's taking place in our external world, what's taking place in our internal world." [I ask if he believes the image is artistic in nature.] George says, "Yes, you can draw connections between the microscopic and the macroscopic" (personal communication, February 10, 2016).

Ralph, science teacher 3, proclaims, “Wow, that so looks like a planet, but it’s not.” [I ask why he says this.] He thinks for a moment and says, “It’s too round. But you could almost buy these as moons. [He points to small dark spots on the right half of the ‘planet’.] Is this more like a lens that has light shining through it?” [I then read the artists’ statement.] Ralph continues, “This [image] would be a great one for trying to identify what it is; in the science realm, from contextual clues – what do you think this is and form your hypothesis.” Referring to the image as a Nano creation rather than a planet, he adds, “From an artistic standpoint, on how you’re able to take something that’s clearly not what you’re seeing and still make it look like if it was” (personal communication, February 11, 2016).

Image 6: *Carbonic Cluster*.

Joanna, art teacher 1, expresses, “Okay, this [Image 6] really has that kaleidoscope feel and I see the Coca Cola image. So, to me, it looks like different colored lenses that were moved, like at the eye doctor.” She continues, “I like that I can see the Coca Cola in there; like I’m looking at something in an artistic way, but from far away I wouldn’t even know – I’d just see color. So, when I get up close, I get to discover

things and that's really fun. So what is it? I'm so excited." [I ask if she thinks the image is from the science department at the university or from a different department.] Joanna responds, "I would think it might come from photography or something where they work with the development of chemicals; and in the developer room where you could transpose images on top of another. That's what it reminds me of – from a dark room." [I tell Joanna she is exactly right and she is very excited; I then read the artist's statement: "This image is one in a survey of plastic objects, in this instance, a double-exposure of two arrays of translucent cola cup lids. The recording was made using analog photographic materials and the colors are the compliments of those seen in visible light" (Sonnichsen, 2013).] Joanna adds, "I loved that in photography, too! Well, that's what art is – you have to know the rules so you can break them. That's so cool!" (personal communication, March 4, 2016).

Helen, art teacher 2, reacts, "Oh my, eggs – wait a minute – it's got Coca Cola all over it. So it must be some kind of film, like an X-ray of Coke cans or something. So I have no idea what it is, but I really like it – the overlap, the transparency, the new shapes. But I don't know exactly how they did it." [I then read the artist's statement and say it's from the art department at the university.] Helen says, "Oh! It's cool! It has a very organic quality, which is interesting because it's not. [It's] still good as scientific art because he's using double-exposure with the color; and he's commenting on a branch of environmental science" (personal communication, March 2, 2016).

Art teacher 3, Lisa, comments, "I see Coca Cola – it looks like there's a bottle cap? Yes, bottle caps put together; and looking through something that projected light elsewhere. I don't know how that was created, and I'm not sure exactly what I'm looking

at. It's more like a collage of colors – a circular thing." [I ask if she thinks the image is from the art or science department.] Lisa replies, "I can see this as [from the] art department; as a collage-type painting, image, photograph, or Photoshop image" (personal communication, March 3, 2016).

[I then read the artist's statement.] She has a more enthusiastic reaction to learning that these are cola cup lids, but it does not seem like she understands the photographic process used to make the image.

Science teacher 1, Jennifer, says, "Okay, something about Coca Cola. It's pretty – lots of color. I like that – color is good. I have no idea what it is." [I ask her if she thinks this image is more on the scientific side or the artistic side of the scale.] Immediately, she answers, "Art. The color dispersion looks more intentional than the others and it has Coca Cola product built into it; whereas none of the others had anything like that" (personal communication, February 6, 2016). [I then read the artist's statement; she does not add any further perspective.]

George (science teacher 2) describes, "Reminds me of a kaleidoscope – where you see different colors coming through; you turn it and get a picture [and] turn it some more and get a different picture, different arrangements. I see Coca Cola on there now; I didn't see it at first." [He is now more curious.] George asks, "Bottle caps? I don't know what it is now. I wouldn't have thought that would be something with science, but maybe there's something – have no clue now." [I then read the artist's statement.] He continues, "We get into some of that in physics where they get into the different compliments in terms of light being absorbed versus light being reflected. We have a carbon world; we're trying to reduce our carbon footprint, so to speak" (personal

communication, February 10, 2016). George believes that this image is a good bridge of art and science.

Ralph, science teacher 3, looks closer at the image and exclaims, "Oh well the Coca Cola kind of gives it away! It looks like almost, I want to say, bottle caps. Is this an X-ray of bottle caps?" [I then read the artist's statement and ask if he thinks it's from a science department or not.] Ralph says that it is hard to say, but he is going with: no. He adds, "If we're going with carbon footprint, that would yell or scream for a biology or life science class. In chemistry, you could talk about photosensitive chemicals and how light affects those. From a physics standpoint, you could talk about color addition and subtraction again" (personal communication, February 11, 2016).

Image 7: *Year of the Dragon*.

Art teacher 1, Joanna, comments, "This [Image 7] reminds me of some kind of attraction, like magnets – how they attract and repel each other. From an art standpoint, I see organic shape, positive/negative space, movement – how my eye moves around the line; it has an active feel, not stagnant like the other ones." [I then read the artists' statement: "Unique patterns of crystalline growth of valence tautomer out of a dichloromethane solution. Crystal branches grow out onto a planar surface but turn to avoid growing into one another. When they cannot grow any further, they collapse into

spiral shapes forming dragon heads" (Rice, Schmidt, and Bruce, 2012).] After hearing the title, she says, "Oh yeah, I see the dragon heads! Wow, so there is something about it repelling itself; that's so neat, they all need their own space." Joanna contemplates art-related ideas after discussing this image. She reflects, "It would be interesting to play with solutions more for grounds [backgrounds for artworks], and how things work together. Even if you're just teaching something as basic as the elements of art – to know these other [science] things is that much more exciting, you know?" (personal communication, March 4, 2016).

Helen, art teacher 2, describes Image 7 by saying, "That looks like some kind of weaving or somebody had fun with magnets. It's very organic but I'm not seeing any stitching or anything, so it could be some kind of interesting magnet play. But [it's] curvilinear, biomorphic, [has] contrast, [and is] very plant-like." [I then read the artists' description of the image.] Helen replies, "Yeah, I can see the dragons. Oh that is really cool! That is so cool!" She says that this totally changes her perspective – knowing about the growth patterns and why it happens. Helen concludes, "So each one [dragon head] is the result of the one next to it" (personal communication, March 2, 2016).

Lisa (art teacher 3) explains, "I think of a really zoomed up picture of a quilt. [It] looks like sewing of some kind of fabric; or rice, little beads of rice. It looks like a pattern because it has these curved swirls to it." [I then read the artists' statement.] Lisa answers, "Cool, that's neat" (personal communication, March 3, 2016). The name of the image changes her perspective a bit because she acknowledges the dragonheads. However, she does not comment any further.

Jennifer, science teacher 1, says, “I have no idea what it is, but it looks cool. I like the pattern of it. At first I thought it was iron filings, but I would never see them make that pattern. Then I thought: butterfly wing. No idea.” [I read the artists’ words about the image.] Jennifer replies, “Cool. Awesome” (personal communication, February 6, 2016). Similar to Lisa, she does not offer any more perspective regarding this image.

Science teacher 2, George, exclaims, “My goodness. Almost looks like paleontology where you see the ferns that are in rocks. I don’t like it as much as the others. It’s almost a dull color – I like the brighter colors in terms of the pictures. It almost looks like a bad wallpaper pattern [laughs].” [I read the artists’ explanation of the image.] George responds, “I can see the dragon heads – yes!” (personal communication, February 10, 2016).

Ralph (science teacher 3) comments, “Wow, this looks like something that grows on the side of a house or something, but in a nice way. Oh look there’s a little dragonhead right there. Let’s see, this yells biology – looks almost like a plant growth, but I don’t see much of a stem. Is this a bacterial cluster?” [I then read the artists’ statement; when I recite that it’s a crystalline growth, he becomes very excited and begins to discuss applications of the image.] Ralph continues, “They’re avoiding each other [the growths] because of charges and fields not because they see each other – you can get into that aspect. You can apply this to art where you could charge plates and form some sort of art structure from there” (personal communication, February 11, 2016).

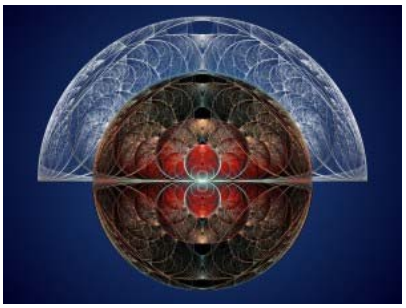

Image 8: *Don't Forget Your Umbrella*.

Art teacher 1, Joanna, states in response to Image 8, "Oh my gosh. Okay, this is cool. This reminds me of insect skin or wings, or their eyeballs – like a thousand eyes in one. So I guess that's the science part that I see. For art, I see that radial/spiral pattern, positive/negative space, symmetry – a weird balance." [I then read the artist's statement: "This digital artwork was created with a fractal software program. Fractal patterns often resemble structures in nature, and many viewers enjoy identifying familiar plants or animals, similar to 'cloud watching.' The delicate lines in this image are similar to the vein patterns found in leaves" (Barrow, 2014).] Joanna responds, "I see the leaves thing, but I still go with insects. It's cool that it's made on a computer – I actually think I've seen programs that do that. There's definitely applications out there, so you could make one on an app and use it for art" (personal communication, March 4, 2016).

Helen (art teacher 2) describes, "Oh my, [it] looks like something out of Dune (a 1980s science-fiction movie). I see a nautilus. [It] looks digital – very cool and futuristic. It looks digital because of how clean and crisp it is – you can't draw that." [I then read the artist's statement, mentioning the fractal software.] Helen answers, "Of course! I can also see the vein patterns, but they should be opposite; I study leaves" (personal communication, March 2, 2016).

Art teacher 3, Lisa, exclaims, “Oh cool, I feel like it’s definitely art-created. [It] looks like some kind of drawing or painting. I almost see like another world with a dome over the world. [It] just looks like art to me, like it was created for appeal – because it’s balanced and symmetrical; it feels comfortable.” [I then recite the artist’s statement.] Lisa replies, “Oh okay yeah, I can see the veins of the leaves; and it has a highlight-type part in the middle, which looks like the stem of the umbrella” (personal communication, March 3, 2016).

Science teacher 1, Jennifer, asks, “Eyeball? No, hmm, no idea.” [I then read the artist’s statement.] She says, “I’ve heard of fractal patterns before. I see that now that you say it, but I also imagine the eyeballs of a fly or the wings of a fly. But this is just totally computer generated?” [I point out that this image is related to math, but it is labeled as scientific art; so I ask if she thinks that it can still relate to science.] Jennifer replies, “If it goes back to the plants and animals part, it could. Even if it’s not truly them [plants and animals], it’s supposed to resemble them, so yes. It looks like a spider in the middle” (personal communication, February 6, 2016).

George (science teacher 2) immediately remarks, “Oh, I like the picture. I’m not sure what it is, but I like the picture.” [I ask what he likes about it.] He responds, “The different color patterns; I like the light – it almost looks like a hat or a lamp shade. From the very center, it almost looks like a spider. It almost looks like a jellyfish surrounding something. Again, I like the colors (the reds); the outside transparent material; I have no clue what it is though.” [I read the artist’s description.] George mentions that he understands fractal patterns and sees the compatibility of math and technology. He

concludes, “I like that. I was thinking of a Tiffany lamp shade; yes, very intricate patterns” (personal communication, February 10, 2016).

Science teacher 3, Ralph, explains, “I think this is my favorite. It is just very aesthetically pleasing. Oh wow, this is so symmetrical. I have no earthly clue of what this could be.” [I then read the artist’s statement.] Ralph says, “I think there’s an application of fractals to high end scientific equations. I can’t swear to that. You can definitely use this as a segue because most people don’t even know what a fractal is!” (personal communication, February 11, 2016).

Concluding Thoughts.

After taking in each participants’ responses to the scientific art images, I concluded these interviews with a few closing questions. First, I asked each teacher if there was an image that they liked the most. Then, I asked if, after viewing and discussing these images, the teacher sees connections between art and science; or believes that the images successfully connect art and science. Last, I asked the teacher to share any closing thoughts.

In response to a preferred image, Joanna (art teacher 1) says, “I definitely like the photography one [Image 6]. I liked the ones where you’re discovering things and finding compositions in there – the light and the cells and the first one, those are my favorites.” She adds, “When I found out the last one [Image 8] was made on a computer, I was like: oh that’s not the same – it wasn’t found in nature.” Regarding science and art connections and closing thoughts, Joanna comments, “I think it’s definitely broadened my perspective a little bit – to even just put it on my radar to think about those kinds of

things. I was trained to be in my room doing art, so I think that's neat – anytime you're connecting things, it's a good thing!" (personal communication, March 4, 2016).

Helen, art teacher 2, comments that her favorite image is Image 4, saying, "It's beautiful – the patterns and the organic growth. I really like fractals a lot. It is so amazing that you can look under a microscope and see something like that." In reference to science and art connections and closing thoughts, Helen reflects, "You've just kind of blown my mind. I think those images are really cool! I definitely see the connections between art and science in the images. They help me to appreciate science a lot more" (personal communication, March 2, 2016).

Art teacher 3, Lisa, states, "I like the second one [Image 2] a lot because it reminds me of *Waterlilies* [Monet's painting]." In response to science and art connections and closing thoughts, she shares, "I think everything you showed was that. Seeing something in a different light – even really up close or far away – really gives a different perspective, which comes from the science part visually coming to the art world" (personal communication, March 3, 2016).

Science teacher 1, Jennifer, responds, "I really like the image with the bubbles [Image 3] because of the colors of light and the physics involved." Regarding science and art connections and closing thoughts, Jennifer shares quite a lot of perspective:

> I feel like learning more about the images changes my perspective a lot because I was trying to think of things that I could have my kids do, not what I could have my kids find. I feel like, with chemistry, you grow a crystal in a cup with a string, and you've got some cool stuff that you can take pictures of or draw or paint or whatever. You know, the crystalline

> structure was in several of them [the images]. I mean that's huge in chemistry. The color and light – that's huge in physics; that was in quite a bit of them. I feel like just being more open to noticing that, and where you could talk about that; or do something with that makes it way more applicable than what I was imagining before. Not that I didn't see it, but I feel like I can see more of it now. I just wasn't going that way when I was thinking about it, you know; which is why I said with the help of someone who knows what they're talking about, I feel like that could totally happen - to bring the two [art and science] together. (personal communication, February 6, 2016)

Jennifer concludes by expressing that she thinks these are good ideas – noticing and applying the connections between art and science in the classroom.

George (science teacher 2) comments that he really likes Image 8, saying, "I like the light and the different color patterns; the intricate patterns remind me of many things, like the Tiffany lamp." In reference to science and art connections and closing thoughts, George also shares a great deal of perspective:

> If we went that direction [connecting science and art], you could do a lot of research with Google imaging and you'd say: okay, here's a whole series of images, let's find out what created the images. Or vice versa: let's look at the different science pictures, which can you think of as art? And maybe try to create those kinds of things. You could do a whole different genre of different artistic patterns, and look at the patterns and see what you could find; and see if they [students] can find something similar in the science

> world – the DNA structures, crystal formations, etc. See if they can find commonality with the art patterns or movements – yeah, I could see that. I truly believe that integrating art is the way to go. I can see from my own kids – their artistic nature was brought out by the band program. I can see my daughter's artistic nature. I think every kid should have the opportunity to explore the artistic nature; it's just a question of can we make it work here at the high school level. (personal communication, February 10, 2016)

Science teacher 3, Ralph, says about Image 8, "I think this is my favorite – it is just very aesthetically pleasing." Regarding science and art connections and closing thoughts, Ralph replies, "For art, if you know why you do certain things, versus just how you do it, then you can expand out on that with the science. Understanding the relationship between art and science can show students how to apply and make connections that they wouldn't normally make" (personal communication, February 11, 2016). He agrees that the scientific art images demonstrate those connections.

Triangulation of Data and Emerging Patterns: Interview Questions Analysis

After reviewing and further analyzing the data, I have compiled the art teacher perspectives and the science teacher perspectives, along with my perspective, according to themes. I arrived at these themes by analyzing the data and looking for patterns in the responses of the participants. The themes are then grouped according to the interview questions, under the proceeding subtitles. These themes that emerged from my analysis are: teachers felt 1) both art and science have concepts/aspects that are difficult to

understand; 2) a curiosity and interest in learning more about certain aspects of each other's subjects; 3) commonalities between art and science are: creativity, discovery, problem solving, thought process, and use of visuals; 4) in favor of integration, with a need for guidance on how to do and apply it – logistical issues; 5) in favor of incorporating the other subject's concepts into their lessons, with a willingness to learn more; 6) students would benefit from learning art and science concepts together; 7) an ASK curriculum is feasible in the high school setting; 8) in favor of collaborating with one another to further develop this type of curriculum. Although the participants were interviewed separately, it is interesting to discover these patterns that developed from their responses.

Hesitation versus curiosity.

First, this section incorporates Q5 and Q6, which ask the art teachers about their thoughts on science and if they have any interest in learning more about the sciences. The science teachers are asked the same questions regarding the visual arts. The themes that developed from the participants' responses are: teachers felt 1) both art and science have concepts/aspects that are difficult to understand; 2) a curiosity and interest in learning more about certain aspects of each other's subjects. The analysis of these two themes is provided in the following paragraphs of this section.

Q5: From the art teachers' perspectives, science: is difficult, with many concepts that are hard to grasp; is interesting, as far as testing hypotheses, labs, natural science, biology, anatomy; is widespread, practical, useful, and important; is creative, involves discovery, and is not isolated; and is somewhat boring, not intriguing, except for creating projects.

From the science teachers' perspectives, art is out of their realm. They lack knowledge about it or do not "get" a lot of it; they do not see how it's art. Art is creative and rich. It includes paintings, sculpture, photos, and moving types; in particular, classics come to mind, like the Sistine Chapel. As far as abstract art, they don't like it and prefer realistic art. These responses led me to the theme that teachers felt that both art and science have concepts/aspects that are difficult to understand. The art teachers named many facets of science, including that it has many concepts that are hard for them to grasp. In turn, the science teachers had similar responses in that art is out of their comfort zone. They do not understand a lot of it, especially abstract art.

Q6: From the art teachers' perspectives, two teachers say yes to learning more about the sciences – they love learning about how things work and where we come from. They are curious people and especially like biology, anatomy, and natural science. The third art teacher says that she is not as interested in learning more about the sciences. She respects science but is not intrigued enough to seek out more information.

From the science teachers' perspectives, they all say yes to learning more about the arts. One science teacher is all about learning more artistic knowledge, but is anxious about trying to make art. The second science teacher specifically mentions learning about incorporating more art into science, and learning about 3D modeling. The third science teacher says yes to learning the historical aspects, techniques, and applications; but is also dissuaded by the art making. These responses led me to develop the theme that teachers felt a curiosity and interest in learning more about certain aspects of each other's subjects.

As an art teacher, I can understand the science teachers' hesitation in trying to make art. I can also acknowledge that many aspects of science are hard to grasp. I agree with both groups of teachers in that acquiring new knowledge is a wonderful thing – being curious people encourages us to ask questions and to continue learning about the world around us. This joy of learning is something that we can and should pass on to our students.

Commonalities, integration, and knowledge attainment.

Next, this section incorporates Q7, Q8, and Q9, which ask the teachers about commonalities between art and science, the integration of art and science, and integrating art or science concepts into lessons. The themes that emerged from the teachers' responses are: they felt 3) commonalities between art and science are: creativity, discovery, problem solving, thought process, and use of visuals; 4) in favor of integration, with a need for guidance on how to do and apply it – logistical issues; 5) in favor of incorporating the other subject's concepts into their lessons, with a willingness to learn more.

Q7: From the art teachers' perspectives, the commonalities are: process, sketches (coming up with a hypothesis and testing it); media (understanding your resources and getting the most use out of them); creativity, problem solving, process, craft and categories; types of thinking – right-brained and left-brained, or creative and practical sides; and research.

From the science teachers' perspectives, the commonalities are: design (engineering and manufacturing); visuals (diagrams, sketches); anatomy; beauty and aesthetics (evolution and nature); 3D models (sculpture); thought process (creativity,

pushing boundaries, expanding what already exists, application to new contexts); subjectivity; and problem solving.

When I think of the commonalities between art and science, I think of creativity, problem solving, questioning/hypothesizing, experimenting, and subjectivity. These ideas brought me to the theme that teachers felt the commonalities between art and science are: creativity, discovery, problem solving, thought process, and use of visuals. I pinpointed the most common responses between art and science teachers; and was pleasantly surprised that both groups felt there are quite a few commonalities between the subject areas.

Q8: From the art teachers' perspectives, they are all in favor of integration. They believe it will help with understanding, but they also consider the logistical issues – how would it work; they would need more information.

From the science teachers' perspectives, they are also all in favor of integration over specialization. They also say that they would need guidance as to how to do it; that it should be done in common units; and it depends on how you apply it – so that it will be a benefit and not a detriment to either discipline.

These answers led to the theme that the teachers are in favor of integration, with a need for guidance on how to do and apply it – logistical issues. I am in favor of integration, but I agree with all of the points my colleagues have made – there are many factors to consider, as explored in Chapter 5.

Q9: From the art teachers' perspectives, they are absolutely in favor of integrating scientific concepts into their art lessons and are willing to learn more. They believe it's probably already happening without recognizing it. As we dove further into discussion of

this question, they came up with more ideas of what they thought were scientific aspects of their lessons. They would like to be able to recognize the science and learn more about it, in order to better educate their students.

From the science teachers' perspectives, they do not integrate much at the moment, but try to apply art where possible. Similar to the art teachers, they came up with ideas of what they thought were artistic aspects of their lessons. They would like to incorporate and learn more. These teacher perspectives developed the theme that teachers are in favor of incorporating the other subject's concepts into their lessons, with a willingness to learn more.

I feel the same way – I would like to learn more about the scientific concepts that we apply in art, so that I may better understand and explain these to my students. When I have explained common artistic and scientific concepts to my students, they always ask questions and show interest in learning more. This is part of my inspiration to develop more collaborative curriculum ideas.

Agreement on concepts, curriculum, and collaboration.

Last, this section incorporates Q10, Q11, and Q12, which ask the teachers if they believe students would benefit from learning artistic and scientific concepts together, if a curriculum that focuses on this would be feasible for high school, and if they would be willing to collaborate with other art/science teachers? The themes that surfaced from the participants' responses are: teachers felt 6) students would benefit from learning art and science concepts together; 7) an ASK curriculum is feasible in the high school setting; 8) in favor of collaborating with one another to further develop this type of curriculum.

Q10: From the art teachers' perspectives, they all believe students would benefit. There would be: higher levels of learning for both sides – using more of one's brain; remembering things on multiple levels; and increased understanding for students on both the art and science sides of the coin.

From the science teachers' perspectives, they also believe students would benefit. There would be: increased connections, especially with specific topics; more options for the students, for those who have an interest in both subjects; breaking down of barriers for students; and application of knowledge in new contexts.

The theme that I developed from these responses is that teachers felt students would benefit from learning art and science concepts together. Both the art and science teachers believe in this aspect and provide support as to why. I agree with both groups of teachers that students would benefit from learning artistic and scientific concepts together. I have also considered the higher levels of learning, increased understanding, and connection making; as well as enhanced appreciation of both disciplines.

Q11: From the art teachers' and science teachers' perspectives, they all feel that an integrated art and science curriculum is feasible in the high school setting. They provide important considerations, which are reviewed in Chapter 5. The theme developed from these responses is that teachers felt an ASK curriculum is feasible in the high school setting. I also believe that the ASK curriculum is feasible in the high school setting, but there are many factors involved such as time, structure, implementation, and resources.

Q12: From all of the teachers' perspectives, they are all willing to collaborate with one another to brainstorm ideas and come up with a structure for the curriculum. Therefore,

these responses led me to the theme that teachers felt in favor of collaborating with one another to further develop this type of curriculum.

I will elaborate on my perspective, this future collaboration, and what the ASK curriculum could look like in the following chapter.

Scientific Art Image Conversations Analysis

I have taken the participant responses to the scientific art images and compiled these into eight tables, one for each image. Each table includes the artistic aspects and the scientific aspects of the image, as mentioned by each teacher; as well as his/her perspective of the image. I then analyzed these data to look for commonalities in the thinking processes of the art teachers and the science teachers; and to gain further teacher perspective regarding art and science collaborations. As seen in Table 1, the responses were provided by the art teachers and the science teachers with regard to Image 1.

Table 1

Summary of Teacher Responses to Image 1: Skyline in the Snow

Teacher	Artistic Aspects	Scientific Aspects
Joanna (Art Teacher 1) Perspective: She's very excited/enthusiastic to learn what the image is; can see it as scientific art, esp. because they added color	-Monochromatic colors, value, contrast, line, texture, pattern. -Some kind of buildings -Salt with watercolors -Some color theory	-Cross-section of frozen crystals -Crystal/ice -Salt is a crystal
Helen (Art Teacher 2) Perspective: She loves the title; thinks it's rightly classified as scientific art because of great contrast, texture, interesting positive and negative space, and repetition with variation; enthusiastic about it	-Monochromatic -Some kind of buildings or structures in space -Likes the blue – more atmospheric -Cool as an image that an artist can create; has visual merit	-Some kind of crystals -Naturally occurring in some way
Lisa (Art Teacher 3) Perspective: She likes it; can see it as scientific art and can see the buildings after hearing the title	-Use of palette knife because of the streakiness of the paint -Looks like a print (print-making)	-Crystals, ice, or cracks (she points to and describes this)
Jennifer (Science Teacher 1) Perspective: After the explanation, she sees the crystals, but says she would've never known that's what it was; thinks it's artistic because it looks really pretty with lines, shapes, and shades – that's what art is to her.	-A lot of blue, different shades of blue	-Inside of a cave with stalagmites and stalactites
George (Science Teacher 2) Perspective: He likes the idea of it being a skyline, but it looks exactly like what he thought it would be; likes the image; makes a suggestion for use in classroom	-He likes the colors	-Crystal structure, ice crystals -Thousands of salts out there; this is how they dried – one of seven shapes
Ralph (Science Teacher 3) Perspective: He makes a suggestion for use in classroom; is not sure what the image is, but sees many different things; can see it as scientific art -scientific part is explaining it for analysis; creative aspect of what could it be, how can you recreate this?	-Looks like a cityscape	-Stalactites/stalagmites or a crystal

For the artistic aspects of Image 1, all of the teachers mentioned the colors except Lisa (art teacher 3) and Ralph (science teacher 3). Ralph does say that the image looks like a cityscape; Joanna (art teacher 1) and Helen (art teacher 2) also describe the image resembling some kind of buildings. This is quite interesting because the artist states that the image reminds him of the New York City skyline after a blizzard. Lisa's answer is the only one that does not share commonalities with those of the other teachers. Regarding the scientific aspects of Image 1, all of the teachers except Jennifer (science teacher 1) describe crystals. Jennifer does, however, mention the inside of a cave with stalactites and stalagmites, which Ralph (science teacher 3) also mentions. Interestingly, the artist states that the image is of salt when it dries, and salt is a crystal.

Looking at the perspectives regarding this image, all of the teachers except Lisa (art teacher 3) are enthusiastic in their responses. Perhaps this relates to her being the teacher with the least teaching experience. The other teachers have more experience with lesson planning, team planning, and curricula, which influences their ability to offer more perspective. Joanna (art teacher 1) is excited to learn what Image 1 is, and discusses the addition of color as support to classify the image as scientific art. Helen (art teacher 2) is also enthusiastic about the image and loves the title. She agrees that the image is scientific art because of many artistic principles that are present. Lisa (art teacher 3) says that she likes the image and can see it as scientific art, but offers no further support as to why. Similar to the interview question responses, she seems to possess less enthusiasm regarding art and science collaboration. Jennifer (science teacher 1) mentions that she would never have known the image was of crystals – even though she is a science teacher. Interestingly, she describes the artistic aspects of lines and shapes as support for

the image being scientific art. George (science teacher 2) says that he likes the image and likes the idea of a skyline, but concludes that it was exactly what he thought it would be – crystal structure. He sees it as scientific art and offers suggestions for classroom use as support. Ralph (science teacher 3) also makes suggestions for classroom use of the image and can see it as scientific art. He supports this by mentioning scientific analysis and creative aspects of recreating the image.

This image visually demonstrates the collaboration of art and science, and I wondered if the teacher participants would see this collaboration. It is encouraging that all of them did; and all but one teacher offered support as to why. As shown in Table 1, the art teachers and science teachers have similar methods of thinking because their answers had commonalities. They saw both artistic and scientific concepts in Image 1, and described aspects that fit with what the artist was demonstrating – before they heard the artist's statement. If these similar thinking processes already exist within the art and science teachers, then collaboration should serve to strengthen the bond of their subject areas.

As seen in Table 2, the responses were provided by the art teachers and the science teachers with regard to Image 2.

Table 2

Summary of Teacher Responses to Image 2: Easter Basket

Teacher	Artistic Aspects	Scientific Aspects
Joanna (Art Teacher 1) Perspective: She gets very excited about ideas and brainstorms two art/science lessons relating cells to a self-portrait	-Pattern, shape, contrast, analogous/split-compliment color scheme, diagonal movement with eye following the green around the image	-Cells of some sort -Biology
Helen (Art Teacher 2) Perspective: She loves the title; thinks it's fascinating and beautiful; amazed by the art inside of the body	-She likes the color palette-analogous with a touch of pink -She likes the variation of shapes with repetition -Good sense of unity	-Some kind of multiplying in a petri dish
Lisa (Art Teacher 3) Perspective: She thinks it's a nice image; says she can definitely see the cells after hearing the artist statement, but still sees what she originally said	-She thinks of alcohol dissolve with paint -Reminds her of a modern version of Monet's *Waterlilies*; describes the colors	-Does not mention any
Jennifer (Science Teacher 1) Perspective: Before hearing the artist statement, she was thinking the scientific art had to be something that's made, not something that's natural; thinks the image is cool and can see the beauty in the art of science	-Very colorful, with the help of injected dye	-Some cellular kind of thing, maybe an onion
George (Science Teacher 2) Perspective: He mentions an activity the students do with staining an onion skin and looking for patterns; relates the science and art	-Pattern -Use of different dyes -Commonality in the structures	-Cell structure -Nucleus, fat cells, cell structure, cell walls
Ralph (Science teacher 3) Perspective: He gives examples of how the image could be used for biology, chemistry, and art	-Pattern	-Biology cell group -Skin cells

Concerning the artistic aspects of Image 2, all of the teachers apart from Ralph (science teacher 3) describe the facet of color. Joanna and Helen (art teachers 1 and 2, respectively) include other elements of art, which relate to analyzing artworks. Lisa (art teacher 3) compares the image to a famous painting by the Impressionist painter Claude Monet; this is fitting because she is the painting teacher at the school. Jennifer and George (science teachers 1 and 2, respectively) point out the use of different dyes to produce all of the colors in the image. Science teachers George and Ralph and art teachers Joanna and Helen all mention pattern when viewing Image 2. Interestingly, the title of *Easter Basket* does evoke the thought of pastel colors (pinks, blues, yellows, and greens); as well as the pattern of similar shapes of Easter eggs. Just like the artist, these teachers all saw color, pattern, or both in this fascinating image.

As far as the scientific aspects of Image 2, all of the teachers except Lisa (art teacher 3) discuss cells or cell structure when viewing the image. Lisa does not mention any scientific facets of this image – again showing her lack of enthusiasm with the scientific parts of the art. Her answer sticks to what she knows – painting – because she has not had the multilevel of experiences like the other teachers. In addition, both Joanna (art teacher 1) and Ralph (science teacher 3) describe biology when shown the image. Image 2 is from the Cell Biology Department at the university, so all of the teachers (excluding Lisa) pinpointed this image quite accurately before knowing what it was. The artists mention the colors of the different cells in the image, particularly the green neurons containing a different gene than the others. Intriguingly, Joanna (art teacher 1) describes how her eye follows the green around the image, creating nice diagonal movement.

Regarding the teachers' perspectives of Image 2, Joanna (art teacher 1) again gets very excited about the image and brainstorms ideas for lessons in which art and science collaborate. It is encouraging that I did not ask her to do this, and just from viewing and discussing Image 2, she brainstorms ideas for future collaborations. Helen (art teacher 2) is enthusiastic in her reaction to the image. She thinks it's fascinating and beautiful; and is amazed by the art inside of the body. This image has shown her the potential of natural, biological art. Lisa (art teacher 3) believes the image is nice, but seems to stay within her painting teacher box even after hearing the artist statement. It will be interesting to discover if her thinking methods change as she views more scientific art images. Jennifer's (science teacher 1) method of thinking changes after she hears the artist statement for this image. She realizes that the scientific art can be natural and not just man-made. Also, she believes the image demonstrates the beauty of the art and science collaboration. George and Ralph (science teachers 2 and 3, respectively) both describe activities that relate science and art – classroom exercises that students engage in that can support this collaboration. Joanna (art teacher 1) also brainstormed collaborative ideas. Once again, similar thinking processes are present in both the art and science teachers. Without being asked, three of the teachers (two science and one art) began generating ideas for art and science collaborations – a promising component of future curriculum building.

As seen in Table 3, the responses were provided by the art teachers and the science teachers with regard to Image 3.

Table 3

Summary of Teacher Responses to Image 3: Rainbow Bubbles

Teacher	Artistic Aspects	Scientific Aspects
Joanna (Art Teacher 1) Perspective: She gets very excited when realizing that she does teach the scientific aspects of reflection and refraction; the image makes her happy and she thinks the colors make it exciting; says the image would be great in the digital graphics class	-Curious about the brown background -Color, value, intensity -Thinks of a kaleidoscope -Blues give a calm sense while vibrant reds and yellows make it exciting	-Some kind of chemical or water -Reflection of light -Refraction -Color spectrum
Helen (Art Teacher 2) Perspective: She's intrigued by the desire to look all over the image, like finding Waldo in Where's Waldo; after hearing the artist statement she is impressed and says that the light-bending aspect makes perfect sense	-Like a no focal point kind of painting; more modern -Rainbow color palette -Repetition with variation -Contrast -Eye bounces all over the image	-Water droplets or something reflective
Lisa (Art Teacher 3) Perspective: After hearing the artist statement, she says that she likes the image	-Reminds her of a kaleidoscope	-Water droplets acting as prisms when the light hits them -Looking at water under a microscope
Jennifer (Science Teacher 1) Perspective: She is excited about this image and says she loves it; says this was where her mind went with scientific art; describes a bubble lab they do – like what's in the image, but just do not take pictures	-Colors of light	-Bubbles -Light and physics -Reflection, refraction, diffraction
George (Science Teacher 2) Perspective: He mentions that he teaches where colors come from; he's familiar with bubble technology; in physics, they look at the polarization of light; he can see the artistic nature with physics: light and color; rainbow art	-Rainbow effects -Roy G. Biv colors	-Light shining through little pieces of glass -Light from different angles
Ralph (Science Teacher 3) Perspective: He gets excited about the image; mentions physics where they talk about polarized light; thinks about art and how can you use polarized light in creating an art structure with a fluid or clear material	-Colors	-Light being refracted through a bunch of bubbles -Light and colors

For the artistic aspects of Image 3, all of the teachers mention the colors, either specific colors or rainbow colors. Joanna (art teacher 1) and Lisa (art teacher 3) both say

that it reminds them of a kaleidoscope. Perhaps this is because they teach visual arts classes and deal with a lot of imagery on a daily basis. Joanna and Helen (art teacher 2) provide the most artistic aspects of all the teachers – describing the background, moods of colors, and lack of focal point. This is sensible because of their art-teaching experience. These two teachers have been in the classroom longer than Lisa, who does not go into depth about describing the image. The science teachers describe the colors in relation to light and the effects of light – an area they are more familiar with.

Regarding the scientific aspects, all of the art teachers thought the image was of water or something reflective. They describe reflection and refraction, demonstrating their knowledge of some scientific concepts. Interestingly, Lisa (art teacher 3) also discusses how water acts as a prism when light hits it; and specifically mentions that this image is of water under a microscope. For being the least enthusiastic about scientific concepts, she includes more details that the other art teachers do not. All of the teachers discuss reflection and refraction; however, the science teachers said that the image is of bubbles or glass rather than water. The science teachers also all mention light and its properties – something that they teach frequently in their classes. It is engaging that the science teachers describe bubbles before hearing the title *Rainbow Bubbles*. Perhaps it is because they have labs with students involving bubbles and are more familiar with these visual properties.

Concerning the teachers' perspectives of Image 3, Joanna (art teacher 1) gets very excited when she discusses reflection and refraction with me, and realizes that she does teach these scientific concepts. It is encouraging for art and science collaborations to hear this art teacher's enthusiasm regarding teaching facets of science. Joanna alludes to

the image's use in the digital graphics class at the school. This is after she hears the artists' statement that the image is of liquid crystals used in places like computer screens. These crystals contain special light-bending characteristics that cause interesting rainbow patterns when viewed with polarized light. Image 3 would give students a better idea of the science behind the technology that they use everyday; and how artistic that science can actually be.

Helen (art teacher 2) is impressed with the image and is very engaged by it. She says that the light-bending characteristics make perfect sense, suggesting that she understands this scientific aspect. During the previous interview, she reveals that she teaches light and color in her classes.

Lisa (art teacher 3) indicates that she likes the image, but does not offer further perspective. This is interesting given that she offered more thoughts before hearing the artist statement. Perhaps it made perfect sense and she was satisfied with her initial thinking.

Jennifer (science teacher 1) is excited about this image and says that this is where her mind went with scientific art. She relates the image to the bubble labs that she does with students, stating that they just do not take pictures of their work. This image shows her that the science she has been investigating is also art, which broadens her perspective of what art can be.

This realization also happens with George (science teacher 2). He reveals that he sees the artistic nature with physics, with light and color. In addition, he is familiar with bubble technology and discusses concepts from this image, like polarized light, that he teaches.

Ralph (science teacher 3) also refers to polarized light in his physics classes and gets very excited about this image. He even suggests an application for art classes. Similar thinking processes are evident in the art and science teachers' answers. Image 3 helped them to reflect upon their own teaching, and visually understand art and science working together.

As seen in Table 4, the responses were provided by the art teachers and the science teachers with regard to Image 4.

Table 4

Summary of Teacher Responses to Image 4: Snowflake Robe

Teacher	Artistic Aspects	Scientific Aspects
Joanna (Art Teacher 1) Perspective: She thinks the image is really cool; is amazed at the beauty you can see through a microscope	-Radial design, value, shape, a background vs. a foreground, pattern	-Some kind of cross-section -Some kind of sponge or microorganism
Helen (Art Teacher 2) Perspective: She thinks the image is beautiful; says she really likes fractals; this image causes her to reflect on science and art, and the scientific art bringing appreciation for both subjects, which she loves	-Patterns -Good contrast	-Frost and fractals -Organic nature of the growth
Lisa (Art Teacher 3) Perspective: She can definitely see the image as art; likes the image but does not add further perspective after hearing the artist statement	-Blue and white colors -Monochromatic, good color scheme -Size and movement	-Reminds her of snowflakes -Ice crystals
Jennifer (Science Teacher 1) Perspective: She says that the image probably looked like a flat surface until seen under the microscope, and then the waviness is evident	-Waviness	-Snowflakes -Crystallization, crystals, something dried
George (Science Teacher 2) Perspective: He likes the image and the title; says it's like a set of drapes or a shower curtain; likes that you can look at it and try to find any two patterns alike, like there are no two snowflakes alike	-Patterns -Wallpaper	-Snowflakes, frost -Crystal formation -Delta formation from rivers
Ralph (Science Teacher 3) Perspective: He is enthusiastic about the image; says he can definitely see the application of what an electron microscope does and what you can see from it; mentions that the microscope shows that a surface that looks flat actually has roughness or waviness	-Texture -How to apply different textured materials to make this sort of image	-Snowstorm -Leafy; some sort of algae

As far as artistic aspects of Image 4, perspectives are divided into two groups. Two art teachers (Joanna and Helen) and one science teacher (George) refer to the interesting patterns in the image. Two science teachers (Jennifer and Ralph) and one art teacher (Lisa) include waviness, texture, and size/movement in their responses. Intriguingly, Jennifer's response of waviness is correct; and this is before she hears the artist statement. The artists describe that the surface on which the material in the image crystallized had a wavy structure, giving it a robe-like appearance; this is where the title *Snowflake Robe* comes from.

Regarding the scientific aspects of the image, all of the teachers except for Joanna (art teacher 1) mention snowflakes, ice, or frost. Joanna alludes to some type of sponge or microorganism and, interestingly, Ralph (science teacher 3) refers to some sort of algae. The other two science teachers discuss crystals and crystal formation, which is correct. This is most likely because they are both chemistry teachers, and crystallization is a central facet of their teaching.

Concerning the teachers' perspectives of Image 4, art teachers 1 and 2 (Joanna and Helen) both feel that the image is beautiful. Joanna is amazed by the beauty that one can see through a microscope – a piece of equipment she does not get to regularly use. This image broadens her perspective quite a lot. Helen believes that fractals are beautiful; she reacts this way after hearing the artists' statement, which includes describing the image as a fractal-like spot. Image 4 causes her to reflect on this scientific art bringing appreciation for both subjects. This was one of my purposes during these conversations with the participants. I wanted them to see visuals of present art and

science collaborations, and gain more of their perspective towards this partnership. In contrast to the other teachers, Lisa (art teacher 3) does not offer further perspective after hearing the artist statement. She sees this image as art and describes more artistic aspects than she has for the previous images.

Jennifer (science teacher 1) gives perspective regarding the electron microscope used to view this image, and explains the waviness. Ralph (science teacher 3) mentions the same points about the electron microscope and its ability to reveal a flat surface as really being wavy. It's remarkable how similar their answers are, considering they were interviewed separately. Ralph is excited about this image and recognizes applications to art and science. George (science teacher 2) feels the same way – he likes the image and its title. He thinks of an application in finding patterns in image 4; there are no two patterns alike because there are no two snowflakes alike.

Once again there are strong similarities in the art and science teachers' descriptions of this image. It is interesting to note that the art teachers have more scientific knowledge than they previously may have thought; and the science teachers can see more applications of art to what they do in their own classrooms, like using electron microscopes.

As seen in Table 5, the responses were provided by the art teachers and the science teachers with regard to Image 5.

Table 5

Summary of Teacher Responses to Image 5: Nano World

Teacher	Artistic Aspects	Scientific Aspects
Joanna (Art Teacher 1) Perspective: She is surprised and intrigued to know that it's not a planet; discusses an activity in her art class that would tie-in with this image	-Light and how it affects color -Wonders what the pinks and yellows are	-Looks like a planet; something seen through a telescope
Helen (Art Teacher 2) Perspective: She is not surprised to learn that it's not a planet; believes the image is very creative because they've taken one thing and given us the impression of another	-Pink Floyd -Nice analogous coloration -Good contrast; nice mood: very mysterious	-Planet or marble
Lisa (Art Teacher 3) Perspective: She is not surprised or curious to learn that it's not a planet; says she thinks it can be artistic, but still sees the scientific side more	-The process of creating an image like this	-Reminds her of a planet, like Saturn without its rings -The moon seen through a telescope during an eclipse
Jennifer (Science Teacher 1) Perspective: Says it looks like a planet to her; says it would be interesting to relate an image from the macroscopic to the microscopic and see why they look so similar	-Pretty, lots of color	-One of the planets or a moon -Not sure which planet – maybe one based on gases
George (Science Teacher 2) Perspective: Right away he describes aspects of different planets; he really likes this image – believes it is artistic because the solar system goes back to Galileo when they first looked through telescopes; surprises him to know that it's not a planet – makes you think of a planet in our external world and what's taking place in our internal world	-Size (connections between the microscopic and the macroscopic) -Planets are beautiful; seeing difference between stars and planets -Color	-Planets; astronomy -Connections between the microscopic and the macroscopic
Ralph (Science Teacher 3) Perspective: He asks questions and, after hearing the artist statement, immediately comes up with ideas to use the image for art and science	-Creating something that is not actually what it seems to be	-Looks like a planet but it's not because it's too round -Lens with light shining through it

Concerning artistic aspects of Image 5, all of the teachers except Lisa (art teacher 3) and Ralph (science teacher 3) mention the coloration of the image. They like the multitude of colors that are present. Joanna (art teacher 1) actually wonders what some of the colors are – demonstrating the analysis and question generating process of art. The artists of the image describe the colors that are seen as being reflected by the material they used to craft the *Nano* World. Helen (art teacher 2) is influenced by the mood of the image; she says it's mysterious, which is a pinpoint observation about planetary phenomenon. Interestingly, Lisa and Ralph both describe the process of creating an image like this. Process is an important commonality of art and science, whether it is creating an artwork or developing an experiment. This image is evidence of scientists taking materials to create something artistic – a Nano world that alludes to being a planetary world.

Image 5 is successful with this scientific aspect because all of the teachers describe it as some kind of planet. Helen (art teacher 2) also refers to a marble, suggesting her realization that the image could be showing something big or something small. The artists named this image *Nano World* because they did indeed create something very small. This image is viewed through the eyepiece of a confocal microscope, which increases optical resolution. Joanna and Lisa (art teachers 1 and 3, respectively) discuss something being seen through a telescope, rather than a microscope. This alludes to the macroscopic versus the microscopic, which is also mentioned by Jennifer and George (science teachers 1 and 2, respectively). In addition, these science teachers see the connection-making ability of this image, for students, in comparing the

very large to the very small. Jennifer and Lisa state that this image could also be of a moon; this shows a science teacher and an art teacher (respectively) with the same thoughts. Intriguingly, Ralph (science teacher 3) is the only teacher who says that image 5 looks like a planet, but it's not because it is too round. Perhaps this is because he is a physics teacher who has taught at an art college. He is trained to recognize visual characteristics and he understands the science behind the image. This is an attribute that can be nurtured by an ASK curriculum – understanding how art and science collaborate.

As far as teachers' perspectives of Image 5, two of the teachers – Joanna (art teacher 1) and George (science teacher 2) – are surprised to learn that it is not a planet. Joanna is intrigued with the image and mentions an art activity that will tie in with it. George is inspired and immediately starts discussing the planets. It is interesting that he believes it is artistic when he thinks about Galileo first looking through a telescope. Perhaps George is a thinker like Leonardo da Vinci; he aligns his scientific mind with artistic thought. Both Helen (art teacher 2) and Lisa (art teacher 3) are not surprised to learn that the image is not a planet. Helen is not surprised because, before hearing the artists' statement, she thought that it could be a planet or a marble. She feels that image 5 is very creative because the artists have taken one thing and given viewers the impression of another. Lisa can see the artistic side of the image, but still believes it is more scientific than artistic. She is the only teacher not intrigued by or curious about the image. Lisa's reactions support her earlier statement that she doesn't actively pursue science knowledge – she does not ask questions about this image like the other teachers do. Jennifer and Ralph (science teachers 1 and 3, respectively) both think of applications of the image for art and science classes.

As with the other images thus far, I wonder if the teachers brainstorm ideas for applications to art and science because a seed was planted for collaborations during our first interviews. It is remarkable that, just through discussing the possibility of art and science collaborations, the art and science teachers began to think more along these lines.

As seen in Table 6, the responses were provided by the art teachers and the science teachers with regard to Image 6.

Table 6

Summary of Teacher Responses to Image 6: Carbonic Cluster

Teacher	Artistic Aspects	Scientific Aspects
Joanna (Art Teacher 1) Perspective: She was very excited to be correct about this image; loves the photographic processes; says art is knowing the rules so you can break them	-Kaleidoscope feel -Coca Cola image -Different colored lenses -Photography – developed in a darkroom	-Discovery
Helen (Art Teacher 2) Perspective: She really likes it; believes it's good as scientific art because the artist is using double exposure with the color and commenting on a branch of environmental science	-Coca Cola all over -Overlap, transparency, new shapes	-Some kind of film or X-ray of Coke cans -Very organic quality, but it's not organic
Lisa (Art Teacher 3) Perspective: She can see this more as art than science; has more enthusiastic reaction to learning that the image is of cola cup lids	-Coca Cola -Bottle caps put together -A collage of colors; circular shapes -Collage-type painting, image, photograph, or Photoshop image	-Projected light
Jennifer (Science Teacher 1) Perspective: She says it's more on the artistic side because the color dispersement looks more intentional than the others; and it has Coca Cola product built into it whereas none of the others had anything like that	-Coca Cola -Pretty, lots of color	-Does not mention any, only that she does not have any idea of what the image is
George (Science Teacher 2) Perspective: He reflects on the title and says that we have a carbon world and we're trying to reduce our carbon footprint; agrees that it's a good bridge of art and science	-Kaleidoscope; colors coming through and different arrangement of pictures -Sees Coca Cola in the image after a few minutes -Bottle caps	-Says he wouldn't have thought this would be science-related; has no clue what it is -After hearing the artist statement, mentions physics: light being absorbed vs. light being reflected
Ralph (Science Teacher 3) Perspective: He believes the image is more on the artistic than scientific side; when he hears the artist statement, comes up with many ideas for application in science classes	-Coca Cola	-X-ray of bottle caps -Biology/Life science class: carbon footprint; the eye -Chemistry: photo-sensitive chemicals and light -Physics: color addition and subtraction

Regarding the artistic aspects of Image 6, all of the teachers mention the words Coca Cola that they see. In addition, all of the teachers describe the colors of the image, except for Ralph (science teacher 3). Instead, he focuses on the application of this artistic image to science classes. Image 6 is from the art department at UNC; however, the artist is using photography to explore the environmental issue of our carbon footprint, with a familiar plastic object – a cola cup lid. All of the art teachers discuss the shapes in the image; this is sensible because shape is one of the main elements of art. Interestingly, both Lisa (art teacher 3) and George (science teacher 2) describe the shapes as bottle caps. George also refers to the same visual reminder as Joanna (art teacher 1): a kaleidoscope. Once again, George is the science teacher with the most artistic thought in regards to this image. He has the most teaching experience and yet does not maintain only strict traditional scientific thinking. This is perhaps the opposite of what most readers would expect.

Concerning the scientific aspects of this image, the art teachers all mention different ideas. Perhaps this is because image 6 was produced in a darkroom, using color photo paper and double-exposure to light. The art teachers recognized the artistic side more, but still engaged with terms like discovery, projected light, and X-ray. In fact, Helen (art teacher 2) and Ralph (science teacher 3) both state that this image involved X-rays. The science teachers point out that they do not have any idea what the image is, but all (except Jennifer) discuss its application to science in different ways. This is encouraging for collaborations because this is the only image that is not from a science department at the university, and the science teachers still found it useful for teaching scientific concepts.

After hearing the artist statement, all of the teachers respond positively in their perspectives. The art teachers all have an enthusiastic reaction to learning the intent of this image. Joanna (art teacher 1) is excited to learn that she correctly identified the photographic processes involved in making this image; and that the artist is pushing the boundaries of art. Helen (art teacher 2) believes it is fitting as scientific art because the artist is commenting on environmental science. She is reminded that artistic and scientific qualities can come together to make a statement. Lisa (art teacher 3) has an enthusiastic reaction to learning that the image is of cola cup lids. This is positive, however, Lisa does not seem like she understands the photographic process used to make this image. Despite this, she does not ask any questions to improve her understanding, while the other teachers do.

The science teachers all see this image as more on the artistic side than the scientific side. George (science teacher 2) mentions that image 6 is a good bridge of art and science. Both he and Ralph (science teacher 3) immediately conjure ideas for application of this image in different science classes. This is encouraging that these science teachers can apply even the most artistic of images to science. There have been interesting commonalities in art and science teacher responses to the images thus far. If there were no similarities present, the future of art and science collaborations at the school would be questionable.

As seen in Table 7, the responses were provided by the art teachers and the science teachers with regard to Image 7.

Table 7

Summary of Teacher Responses to Image 7: Year of the Dragon

Teacher	Artistic Aspects	Scientific Aspects
Joanna (Art Teacher 1) Perspective: After hearing the title, says that she sees the dragon heads; likes the image; mentions applications to the art classroom	-Organic shape, positive/negative space, movement: real active feel, not stagnant like the other images	-Magnetic attracting and repelling
Helen (Art Teacher 2) Perspective: After hearing the title, says that she sees the dragons; loves the image; says it totally changes her perspective: knowing about the growth patterns and why it happens	-Some kind of weaving, but no visible stitching -Curvilinear, contrast	-Having fun with magnets -Very organic -Biomorphic, very plant-like
Lisa (Art Teacher 3) Perspective: After hearing the title, the name changes her perspective because she now sees the dragon heads	-Zoomed in picture of a quilt; sewing of a fabric; little beads of rice -Pattern	-Does not mention any
Jennifer (Science Teacher 1) Perspective: She has no idea what the image is; after hearing the artist statement, she thinks it's cool but offers no further thoughts	-Pattern	-Initial thought was iron filings, but they would not make this pattern -Butterfly wing
George (Science Teacher 2) Perspective: He does not like this image as much as the others; but, after hearing the artist statement, gets excited and says he can see the dragon heads	-More dull colors; he likes the brighter colors -Bad wallpaper pattern	-Paleontology: ferns that are in rocks
Ralph (Science Teacher 3) Perspective: He gets excited after hearing the artist statement; starts to explain further what is happening in the image; thinks of an application to art and environmentalism	-Sees the dragon heads before hearing the artist statement	-Biology: looks like a plant growth, but no stem -Bacterial cluster

In regards to the artistic aspects of Image 7, there are quite a variety of responses. Joanna (art teacher 1) and Helen (art teacher 2) both mention shapes, space, and

movement – all elements of art. They pinpoint the curvilinear, more active feel of the lines and shapes of the image. Helen also has an answer in common with Lisa (art teacher 3), in that they both describe some kind of weaving or quilt. Lisa even includes beads of rice in her description – both teachers show creative thinking with this imagery. In addition, both Lisa, Jennifer (science teacher 1), and George (science teacher 2) discuss pattern in the image. Another common response between an art teacher and science teachers is encouraging for similar modes of thinking and collaboration. George compares the pattern to a bad wallpaper design, and says that he does not really like the dull colors of this image. He prefers the brighter colors of the other images – this is a candid artistic observation from a science teacher. Even the art teachers do not point out this color aspect. Intriguingly, Ralph (science teacher 3) is the only teacher who sees the dragon heads before hearing the title of the image or the artist statement. Perhaps this is, again, due to the art college teacher experience influencing his perspective. It is interesting that the art teachers did not visualize this kind of imagery.

Concerning the scientific aspects of Image 7, both Joanna and Helen (art teachers 1 and 2, respectively) describe the use of magnets in creating this image. Lisa (art teacher 3) does not mention any scientific facets – again supporting her lack of enthusiasm for interpreting the scientific part of these images. Despite this limited excitement for science, however, Lisa states (during the first interviews) that she is willing to collaborate with other art and science teachers, and is curious as to how the whole process would work. So, even though the scientific art images are not as appealing to her as they are to the other teachers, she is not opposed to art and science working together to build new curriculum ideas. Jennifer (science teacher 1) says that she initially

thought the image was of iron filings – a response that relates to the magnet ideas of the art teachers. One can use magnets to manipulate iron because it exhibits magnetic behavior. However, as a chemistry teacher who is familiar with magnetic properties of elements, she recognizes that iron filings would not make this type of pattern. She then thinks of something organic, a butterfly wing. Helen (art teacher 2) also describes the image as being something organic, biomorphic, or plant-like. Interestingly, this response is very similar to the descriptions of both George and Ralph (science teachers 2 and 3, respectively), which include ferns and plant growth. George ties the image to paleontology, while Ralph does to biology. Helen previously mentioned that she loves biology and studies plant growth, which resonates in her reaction to this image.

As far as the teachers' perspectives of Image 7, all of the teachers get more excited about the image after hearing the title and artist statement. The statement describes the crystalline growth that grows onto a flat surface. The crystal branches turn to avoid growing into one another and collapse to form what looks like dragon heads. This is where the title *Year of the Dragon* comes from. All of the art teachers say that they see the dragon heads, after hearing the title of this image. Joanna (art teacher 1) likes the image and mentions applications of it for the art classroom. Helen (art teacher 2) loves the image and says that learning about the growth patterns and why they occur totally changes her perspective. Even Lisa (art teacher 3) states that her perspective changes after hearing the title. Perhaps the scientific art images can show even the most strictly artistic or strictly scientific of minds that this type of collaboration provides a unique learning experience. Jennifer (science teacher 1) likes the image but does not get as excited about it as George and Ralph (science teachers 2 and 3, respectively). George

says that he does not like image 7 as much as the other images, but still becomes very enthusiastic about seeing the dragon heads after hearing the artist statement. Ralph has the same reaction and even goes into further explanation of the image. He also thinks of an application to art and environmentalism. Judging by the teachers' reactions to image 7, it is encouraging for art and science collaborations that this scientific art image can stimulate and change perspectives.

As seen in Table 8, the responses were provided by the art teachers and the science teachers with regard to Image 8.

Table 8

Summary of Teacher Responses to Image 8: Don't Forget Your Umbrella

Teacher	Artistic Aspects	Scientific Aspects
Joanna (Art Teacher 1) Perspective: She likes the image; thinks it's cool that it's made on a computer; says she's familiar with programs and apps that make an image like this, so she could make one and use it for art; says she sees the leaves idea but still goes with insects	-Radial/spiral pattern -Positive/negative space -Symmetry; weird balance	-Insect skin or wings -Insect eyes; 1000 eyes in one -An eyeball
Helen (Art Teacher 2) Perspective: She understands and is excited by the fractal software aspect; says she can see the vein patterns but they should be opposite because she studies leaves	-Looks like something out of Dune (movie) -Looks digital because of how clean and crisp it is -Looks futuristic	-A nautilus
Lisa (Art Teacher 3) Perspective: She says that she can see the veins of the leaves; and it has a highlight part in the middle, which looks like the stem of an umbrella	-Definitely art-created; some kind of drawing or painting -Just looks like art; created for appeal -Balanced, symmetrical; feels comfortable	-Like another world with a dome over it
Jennifer (Science Teacher 1) Perspective: She's heard of fractal patterns before; can see what the artist is saying, but thinks more of a fly's wings or eyes; says it could relate to science if it's supposed to resemble plants/animals	-Computer-generated?	-An eyeball -Eyeballs or wings of a fly -Looks like a spider in the middle
George (Science Teacher 2) Perspective: Right away he says that he likes the picture; understands fractal patterns and mentions math and technology; also math and art	-Different colored intricate patterns -Light; looks like a hat or a Tiffany lampshade -Colors; reds; outside transparent material	-Looks like a spider in the center -Looks like a jellyfish surrounding something
Ralph (Science Teacher 3) Perspective: He says this image is his favorite out of all the images; mentions that this image would be a great segue for lessons because most people don't know what a fractal is	-Very aesthetically pleasing -So symmetrical	-Thinks there's the application of fractals to high end scientific equations

Referring to the artistic aspects of Image 8, there are similarities between art teacher and science teacher responses, as seen in all of the previous scientific art images. Joanna (art teacher 1), Lisa (art teacher 3), and Ralph (science teacher 3) all describe this image as being balanced and symmetrical. Lisa says that the image just looks like art, like it was created for appeal. Ralph mentions that it is very aesthetically pleasing. It is interesting that this image is visually appealing to both this art teacher and this science teacher in the same way. In addition, Helen (art teacher 2) and Jennifer (science teacher 1) pinpoint that image 8 is digital, or computer-generated. They both recognize that it is not something natural or hand-drawn. Lisa also states that this image is definitely art-created, not naturally occurring. These observations are made before the teachers hear the artist statement and they are correct – it is a digital artwork created with a fractal software program. George (science teacher 2) points out the artistic facets of pattern and color, comparing the image to a Tiffany lampshade. He comes the closest to visualizing the dome shape in a similar fashion to the artist, who thinks of an umbrella.

Concerning the scientific aspects of Image 8, Joanna (art teacher 1) and Jennifer (science teacher 1) both state the same ideas – that the image is of insect eyes/wings or an eyeball. Jennifer and George (science teacher 2) together mention that they can see a spider in the center of the image. The other responses from the teachers vary quite a bit – perhaps because this artwork is digitally created. The artist is exploring fractal patterns, which often resemble structures in nature. He says that many viewers enjoy identifying familiar plants or animals (like the spider); and he describes the delicate lines in this image as similar to the vein patterns of leaves (Barrow, 2014). In response to hearing the

artist's statement, Joanna's (art teacher 1) perspective is that she likes the image and the fact that it is made on a computer. She says that she is familiar with programs like the one used to create image 8, and she could make one and use it in her art classroom. She exclaims that she can see the vein patterns, but is set on the idea of insects. Helen (art teacher 2) also understands and is excited by the use of fractal software. She also sees the vein patterns, but makes a keen observation that the patterns should be opposite because she studies leaves. Both of these teachers are open to new methods of making art. In addition, Lisa (art teacher 3) can see the vein patterns and points out a highlighted area down the center of the image that resembles the stem of an umbrella. She relates to the artist's vision for this digital artwork, supporting her statement that this image feels comfortable.

Jennifer (science teacher 1), just like Joanna (art teacher 1), holds to her initial thought of insect eyes or wings; she also says that she can see what the artist is saying. All of the science teachers have either heard of or understand fractal patterns. Ralph (science teacher 3) states that this image would be a great segway for lessons because most people do not know what fractals are. He also discusses that this image is his favorite out of all the images. George (science teacher 2) immediately mentions that he likes this image and also thinks of applications to art, math, and science.

These images visually demonstrate the connection between art and science, and I wondered if the teacher participants would see this relationship. It is encouraging that all of them did; and all but one teacher offered support as to why. As shown in this analysis, the art teachers and science teachers have similar methods of thinking because their interview responses have commonalities. In addition, they saw both artistic and scientific

concepts in all of the images, and many described aspects that fit with what the artist was demonstrating – before they heard the artist's statement. If these similar thinking processes already exist within the art and science teachers, then collaboration should serve to strengthen the bond of their subject areas.

Without being asked, most of the art and science teachers began generating ideas for art and science collaborations – a promising component of future curriculum building. Some of the images helped them to reflect upon their own teaching, and visually understand art and science working together. It is interesting to note that the art teachers have more scientific knowledge than they previously may have thought; and the science teachers can see more applications of art to what they do in their own classrooms, like using electron microscopes. After viewing and discussing the images, I wondered if the teachers brainstormed ideas for applications to art and science because a seed was planted for collaborations during our first interviews. It is remarkable that, just through discussing the possibility of art and science partnerships, the art and science teachers began to think more along these lines. There have been interesting commonalities in art and science teacher responses to these scientific art images. If there were no similarities present, the future of art and science collaborations at the school would be questionable.

Chapter 5

What Will the ASK Curriculum Look Like?

Future Collaborations

Valuable Thoughts and Considerations

The purpose of this dissertation study is: to bring teachers' perspectives to the forefront, to encourage art and science teachers to collaborate, and to gain insight into the development of the ASK curriculum. Gaining the perspectives of my art teacher and science teacher colleagues has proven very valuable when considering art and science integration and proposing a new curriculum. Understanding my colleagues' perspectives has also assisted me in the refinement of my own perspective. First, it is important to comprehend the art teachers' thoughts on science and the science teachers' thoughts on visual art. From my own perspective, science is fascinating and full of discovery; and it builds on previous knowledge to help us understand the world in which we live. I feel the same way about the arts. My art teacher colleagues remind me that there are scientific concepts that are hard to grasp and may be intimidating to a non-scientist. This theme also carries from the pilot study, in which the two art teachers expressed feelings of intimidation when contemplating the many facets of science. One of the art teachers is not very intrigued by science, but this does not dissuade her from the prospect of collaboration with science teachers. The art teachers also feel that science is creative, and they prefer hands-on activities to memorization. The science teachers provide valuable

thoughts on visual art, helping me to see the arts from a non-artist perspective. They feel that art is outside of their realm, with much that is hard to understand. My science colleagues also prefer realistic art to abstract art. Perhaps this preference relates to a scientist's goal of understanding and representing the world through realism rather than abstraction. The science teachers' perspectives remind me that visual art can be seen as intimidating and complicated. As an art teacher, I forget this viewpoint because I am so familiar with the arts. I find that students can be anxious about creating their own art; and once that barrier is weakened, they discover that they can overcome that anxiety.

Two of the science teachers mention this type of anxiety in actually having to make art. They do not feel like they are artistic in nature. These perspectives reinforce my thought that the ASK curriculum can be taught as a Fine Arts elective class. I will explain this further in the upcoming ASK curriculum section. All but one of the teachers expresses a curiosity and willingness to learn about each other's subject matter. This is very encouraging and also reminds me that there will be some resistance and/or hesitancy when proposing new collaborations to teachers.

Through my research, I have discovered many commonalities between art and science. Without prompting my participants with this knowledge, I found that both the art teachers and the science teachers reported several common traits shared by the disciplines. This finding is promising for future art and science collaborations. If the teachers of each discipline do not see these commonalities, then the goal of collaboration and integration may be weakened. One of the science teachers includes a shared aspect of art and science as: pushing boundaries, expanding what already exists, and application to new contexts. This is an important reflection for future art education, and twenty-first

century learners. Since becoming a discipline in the 1960s, art education has adapted to many different contexts and pushed many boundaries. If art and science both expand what already exists, then why not work together to do so in a joint curriculum? An ASK curriculum can show teachers and students that integrating art concepts and science concepts strengthens creativity, discovery, problem solving, and other higher levels of thinking. Art education can reach a broader audience, like science teachers who may have considered themselves on the opposite end of the education spectrum from the arts.

New curriculum ideas are valuable, but also include many considerations. All of the research participants believe the ASK curriculum is feasible in the high school setting, but their first consideration is logistics. How do you implement the course, and how do you check its progress? A pilot course is an excellent idea. There may be resistance from teachers at first, so a successful pilot would be needed to show that the course works. When administrators at the high school want to implement a new discipline system, for example, they bring in teachers from other schools that have tried it and been successful. Then they review and have us try it for ourselves, as a type of pilot. This helps the system to generate momentum and build support. My participants remind me that this is an important step in the curriculum-building process. Teachers and administrators will want assurance of successful implementation. My participants point out that, although there may be resistance, with the right teachers, administrative support, and common goals we can make it happen.

The ASK curriculum would give students an in-between place – a place for them to see the connections between art and science. One of the science teachers points out that the length of the course and the content also need to be taken into consideration.

Would we have enough content to cover a semester or a year? We would need someone who is knowledgeable in many areas of art and science, or we can consider team teaching. This ties in a theme from the pilot study: more training for increased knowledge. During the pilot study, I focused on the art teachers incorporating scientific concepts into their art lessons. This caused them to mention that they would need more training to increase their scientific knowledge. After the dissertation study, I have thought more about this training in the form of collaboration and team curriculum building. The art teachers are willing to learn more about science and the science teachers about art. Even the reluctant art teacher is willing to collaborate and learn from the science teachers, in order to answer her students' science-related questions.

Future Collaborations

All of the participants are willing to collaborate, to brainstorm, and to come up with a plan for the ASK curriculum. The art teachers seem to love coming up with ideas – the creative side. They believe that time and communication is key. Also, they want to get more understanding of the science side. They feel like they would need more science education, and that it will be valuable if the science teachers gained some art education. The science teachers seem to be on the more practical side – not so much idea generating, but being given the topics and coming up with a plan. They say that once the topics are out there, they can run with it and enjoy planning. They would like to have things laid out and then they can expand upon that.

Both the art teachers and the science teachers believe that students would benefit from learning artistic and scientific concepts together. The art teachers mention learning

on multiple levels. These higher levels of learning are facets of education that many teachers are familiar with. Students are more likely to remember something if they are engaged in a process other than just memorization. Art education is process-based, with end products in mind. The art teachers consider this aspect when commenting on combining artistic and scientific concepts. They say that students are more likely to remember information if they create something based on those concepts.

The science teachers consider the increased connections, especially with specific topics. If their students can see the use of science in places outside of the science classroom, it is more meaningful. The students are more likely to remember those connections. One of the science teachers previously comments that we expect our students to see the connections between subjects when they graduate and become adults. As teachers, if we can enforce the connections between the subjects while they are still in school, this will better prepare students for the multi-faceted, twenty-first century thinking that is increasingly in demand. The science teachers also like the idea of more options for the students, for those who have an interest in both art and science. They reflect that they have a lot of artistically talented students, and they would like to learn how to promote that talent. In addition, the teachers believe that learning these concepts together will break down barriers for students. For those students who may shut down because they think science is too hard or that they are not artistic, a combined curriculum can weaken those misconceptions and promote application of knowledge in new contexts. All of the teachers are on board for future collaborations, so it will come down to time and place.

ASK Curriculum

After interviewing and brainstorming with the teachers, I have a much clearer idea of the curriculum process. The first steps are: to gather the teachers together for a group discussion and brainstorm curriculum ideas together. From there, we can come up with a structure, or skeleton, for the course and proceed to gather more research. Just from my initial interviews and conversations with the teachers, many concepts or common unit ideas have been formed. These include: light and color; crystal shape and structure; chemical reactions; molecule modeling; human anatomy; plants and flowers; DNA structure; the clay transformation process; chemistry and history of paint; environmental art; physics and the theater; and art history and the Scientific Revolution. These are concepts that can be further developed through planning and collaboration between art and science teachers. The following paragraphs delve into some of these art and science concepts further.

First, according to the science teachers, light and color is a big part of physics. Color theory is a huge part of visual art – this begins with understanding the color spectrum produced by white light through a prism. Instead of just learning how to mix and apply colors, the students get a view of the science of light and color and why we see the way that we do. Students can be shown scientific art images like "Rainbow Bubbles" and "Carbonic Cluster" for discussions of aesthetics and the effects of light. If these concepts are explained with physics and with art, and then applied in a lab and to an art project, students will see the connections between science and art.

Also, the chemistry teachers discuss crystal shape and structure frequently in their classes. Their students grow crystals and observe the crystalline structure. Shape and form are elements of art that are considered part of the building blocks of art and design knowledge. If students are shown scientific art images like "Skyline in the Snow" and "Snowflake Robe," they can discuss the aesthetics of crystal shape and structure. When viewing artworks, the art teachers describe design principles such as pattern, contrast, and variety. These principles can apply to science as well. One of the science teachers suggests that students can grow a crystal and then create a painting of it.

Next, chemical reactions are obviously a huge part of chemistry. These reactions and bonds are concepts that many students struggle with; and one of the chemistry teacher's comments that she has the students draw these bonds. She sees the artistic nature of many of her students, and their desire to create detailed drawings when they only have time for quick sketches. This type of activity can be fully nurtured in the ASK curriculum. The painting teacher mentions that she has her students apply different materials to paint, such as rubbing alcohol and salt, to produce interesting effects. These are chemical reactions that she says she does not know how to explain to students. Collaborating with a chemistry teacher can provide the necessary information, so that students better comprehend the joining of chemistry and art.

Then, the science teachers explore molecules and their structures, particularly in chemistry. One of the science teachers expresses his desire to learn more about 3D modeling to construct models of molecules, like the DNA structure. This can be a joint effort between himself and the sculpture teacher, who knows how to create 3D models out of many different types of materials. With the ASK curriculum, students can be

given a sculpture project that involves the building of molecules. Through this process, they can learn more about sculpting different materials, as well as observing and translating the DNA structure from a 2D picture to a 3D form.

In addition, the art teachers describe the need to understand human anatomy in many aspects of the visual arts. In drawing, one of the art teachers teaches the bone and muscle structure to students so that they have a better understanding of drawing from life. Anatomy and physiology is part of the sciences. Drawing the different parts of the human body, rather than just studying the visuals from a textbook, can really solidify the higher levels of learning for students. They take that knowledge and learn to observe the details of the visuals, as they apply this to their own creation.

Last, the same concept from the previous example can be applied to aspects of the natural sciences, like plants and flowers. Students can learn the growth cycle and actually grow their own plants. They can keep a sketchbook in which they sketch the plant's growth at different intervals. Leonardo da Vinci created many drawings of plants and flowers in his notebooks. These will be perfect examples to show students the integration of art and science. Environmental art is an area of the visual arts that demonstrates a respect and appreciation of the beauty of nature and/or the human effect on it. There are many artists, like Andy Goldsworthy, who create their artworks from nature and within nature. These artists have to understand their material, whether it is leaves and twigs or trash. Environmental art can be tied to environmental science in that students can make artworks out of trash to reflect on our effect on the planet. This is what the artist of "Carbonic Cluster" does in hopes of causing the viewer to consider our

carbon footprint on the earth. Students can also create powerful messages with this type of art and science collaboration.

As aforementioned, I envision the ASK curriculum to become a Fine Arts elective course. After conducting this research, I realize that one of the vital factors on teachers' minds when considering new curricula is time. Even within separate art courses and science courses, teachers are usually on a time crunch to teach required units to students. If ASK is an elective course, it can supplement difficult concepts in science education through the help of art education. The course can also serve students who are interested in combining art and science together, just as Leonardo da Vinci did and Andy Goldsworthy does. Student artists can take the course to learn how to investigate and incorporate scientific concepts into their art. In this way science education can supplement art education. This has always been my personal and professional goal – to strengthen the value and reach of art education.

After collaborating with the other art and science teachers to create units for the ASK curriculum, it is my hope that the teachers will be able to incorporate some of the units into their own curriculum. It is my personal goal to teach an ASK class in the future, and that the other teachers will be able to team-teach with me. This way they have the ability to teach and experience the units, and bring them more easily into their own classrooms. These experiences would be a part of the pilot course, and would serve to work through successes and failures.

I believe that we are venturing into an exciting time in education. Technology has eliminated boundaries that once existed between the disciplines of art and science; and teachers seem to be more willing to learn and collaborate for the benefit of students.

Next steps for the development of the ASK curriculum are to continue to collaborate and brainstorm with colleagues, and to develop a pilot course to test and present to the school district. I also need to research the administrative side of developing a new curriculum, in order to align with the rules and guidelines of the state.

This research began as a personal journey for myself as an art teacher who is also passionate about science. I consider myself a curious person who loves to ask questions, and I encourage this same curiosity in my students. When researching Leonardo da Vinci and other artist-scientists, I admire their exploration into more than one realm, more than one discipline. This art and science integration inspires me to think of students, as they decide what they want to be when they leave high school. If they have multiple interests, like the arts and the sciences, those interests and connections should be nurtured while they are still in school.

The future of art education is vast with possibility and promise. As artists explore and expand new realms for their art, art education can explore new curriculum ideas and expand on art courses that are offered at the high school level. If art and science collaborations, reviewed in this dissertation, have provided meaningful learning experiences for students, then a full curriculum has hope of the same. The teachers in this study have provided valuable feedback, and are on board to create an ASK curriculum. I am hopeful that this research has provided some insight to other art and science teachers who have considered collaboration, and encourages that collaboration for the future dynamic relationship of art and science.

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